MRI Spine in Low Backache
MADE EASY®

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for the General Practitioners

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Preface

Lifetime prevalence of low back pain is 60–90%. The disease may be caused by injury to soft tissues such as muscles or ligaments, compression of nerves as seen in spondylolisthesis or disc herniation, bone disorders like osteoarthritis, and malignancy. However, an anatomic diagnosis is elusive in 85% of the time and often nonspecific terminology such as "strain" is used. About 97% of cases of low back pain have a mechanical cause, and almost 4% can be attributed to a disc herniation.

Low back pain is the second most common complaint (after the common cold) encountered by primary care physicians, the practitioners. Treating patients with low back pain can be particularly frustrating, at times, for the clinicians, and imaging is a common diagnostic tool used to gather information and direct therapy. Nowadays the practitioners prefer Magnetic Resonance Imaging (MRI) scanning for all their patients with low backaches, as MRI is considered the best single imaging modality of the spine for its ability to demonstrate all of the spinal components—bone, discs, ligaments, fatty tissue, dura, CSF, neural tissue, and blood vessels—with superb contrast resolution. Back pain results from many causes, including degenerative and congenital spinal stenosis, neoplasm, infection, trauma, and inflammatory or arthritic processes. Acquired spinal stenosis due to degenerative joint and disc disease, accounts for the vast

majority of cases. The following structures may be responsible for the origin of back pain:

1. Bone (spondylolisthesis, spondylolysis, osteophytosis)
2. Ligament (hypertrophy of the spinal ligaments, particularly the ligamentum flavum)
3. Facet joint (facet hypertrophy, synovial cyst)
4. Disc (bulging and herniation).

Most often, acquired narrowing of the spinal canal is due to a combination of bone, ligament, joint, and disc disease. The most common location of these changes is the lumbar spine.

Diagnostic tools such as computed tomography (CT) and magnetic resonance imaging (MRI) provide important information that enhance the practitioner's ability to understand the origin of the patient's complaints and make the most appropriate therapeutic choices, be them conservative or surgical.

This book is designed to serve as an introductory guide for those busy practitioners who strive to enhance their clinical skills and ability to provide excellent care to patients suffering from pain due to lumbar spinal diseases. Various diseases affecting the low back are presented with basic imaging studies. Each image has a corresponding line diagram, followed by image interpretation and a brief comment about the disease. Color diagrams are also used to enhance the understanding of the images. It is hoped that after reading this book physicians will become familiar with the MR images and the correlating imaging studies with clinical findings.

This *MRI Spine in Low Backache Made Easy for the General Practitioners* is an effort to help the clinician in the visualization of the lumbar spine by defining normal and abnormal spinal anatomy and pathology in a clear concise manner. This will be attempted by means of high quality images, abundant line diagrams (some of them in color), image interpretation and appropriate comments. A general overview in certain conditions (spine secondaries, disc herniations, etc.) is given in order to give an indepth understanding of the particular condition. This pocket book has 77 (seventy seven) MR images, 91 (ninety one) line diagrams, 15 color images (fifteen) and 6 (six) tables. Almost each MR image has a corresponding line diagram for better interpretation and understanding.

This is neither a textbook of radiology on lumbar spinal disorders nor does it covers the entire gamut of imaging in lumbar spinal diseases. It gives a glimpse of the art of interpretation of lumbar spinal MR images needed for day to day practice. It fills the gap between the theory and practice of lumbar spinal imaging, aimed primarily at busy medical practitioners. This pocket book contains only examples for broad spectrum of lumbar spinal diseases. Covering over forty-disease categories.

G Balachandran

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CHAPTER

1

Basic Principles of MRI

The following text gives a brief introduction to the basic and fundamental physics of MR imaging. The unnecessary physics and technical jargon have been deliberately avoided.

MRI (Magnetic Resonance Imaging) is an imaging modality based on an interaction between transmitted radiofrequency (RF) waves and hydrogen nuclei in human body under the influence of a strong magnetic field.

The simple single steps of an MR examination can be described:

- ❖ The patient is placed in a magnet (MRI scanner)
- ❖ A radiowave is sent in,
- ❖ The radiowave is turned off,
- ❖ The patient's body emits a signal,
- ❖ The signal is received and used for reconstruction of the image.

❖ Normally protons in hydrogen atoms (which are abundant in our body) are moving in a random fashion. Each proton in hydrogen nuclei behave like tiny magnets, always spinning on their axes. The protons behaving like little magnets align themselves when placed in an external magnetic field (Magnetic), but still keep spinning. They are aligned in two ways, either parallel or antiparallel to the external magnetic field depending upon their energy states. The magnetic forces of net aligned protons add up their forces in the direction of the external magnetic field. At equilibrium, net magnetisation is parallel to the main axis of the external magnetic field. This is called *longitudinal magnetisation.*

- A radiofrequency (RF) pulse is now sent in to disturb these protons. The spinning protons are disturbed and they wobble like a toy spinning 'top'. When the RF pulse and the protons have same frequency, the protons pick up some energy from the radiowave, by a phenomenon called resonance (RESONANCE). Thus RF pulse tips longitudinal magnetization into the transverse plane, creating "transverse magnetisation". Some of the protons pick up energy, and go from a lower to a higher energy level. The radiofrequency pulse exchanges energy with the protons. and change their energy state.
- When the RF pulse is switched off, the protons begin to lose their excess energy by a process known as 'relaxation'. which are determined by two time constants, T1 and T2 which are different and independent processes. The electrical signal given by the 'relaxing protons is received by an antenna and is used for generating images (IMAGING).
- The number of free hydrogen nuclei determines the exchange of energy, thereby the relaxation time constants (T1 and T2) and contribute to the final signal. The bound hydrogen nuclei have less signal (e.g. cortical bone), while free hydrogen nuclei have more signal (e.g. fat). Different tissues have different T1 and T2 relaxation times under the same magnetic field. The differences in the relaxation times of different tissues are the key to the excellent contrast among them on the MR image created. T1-weighted images (T1W) are

used for tissue discrimination, while T2-weighted images (T2W) are very sensitive to the presence of increased water and to differences in susceptibility between tissues.

- T1 or T_1 ("T-one") (Spin-lattice, thermal, or longitudinal) relaxation time is measured in milliseconds. T1 reflects the characteristic time constant for spins to align themselves with the external magnetic field. T1 weighted (T1W) sequence are designed to distinguish tissues with differing T1 relaxation times. T1W image is one whose contrast is mainly determined by T1 relaxation time. Tissues with a short T1 time (e.g. fat) appear bright, while tissues with a long T1 time (e.g. water) appear dark in T1W images.

T2 or T_2 ("T-two") (Spin-spin or transverse) relaxation time reflects the characteristic time constant for loss of phase coherence among spins, caused by interactions between the spins, resulting in loss of transverse magnetization and MR signal. T2 weighted (T2W) sequence are designed to distinguish tissues with differing T2 relaxation times. T2W image whose contrast depends primarily on T2 relaxation time. Tissues with short T2 time (e.g. water) appear bright, while tissues with long T2 time (e.g. fat) appear dark in T2W images.

- Both T1W and T2W are used in routine spinal imaging. These two TIW, and T2W imaging proctocols are the basic proctocols upon which several new proctocols are created to get more details about disease processes.
- MR evaluation of the spine requires imaging in at least two basic orthogonal planes. Typically, these include

T1-weighted spin-echo (SE) images (short-echo time [TE], short-repetition time [TR]), and a T2-weighted SE images (long-echo time [TE], long repetition time [TR]).

Disadvantages of MRI (compared to CT scan)

Pertaining to lumbar imaging

1. It has low sensitivity for calcium, therefore cannot diagnose calcification clearly.
2. It has low sensitivity for acute hemorrhage.
3. Scan time is prolonged.
4. Contraindications prevent certain patients from entering the MRI system. Patients with metallic implants like cochlear implant, steel sutures, pacemakers, etc. are not allowed inside the MR scanner.
5. Patients with claustrophobia cannot tolerate the study and some young children may need anesthesia.
6. Intravenous contrast agents may be needed.

Advantages of MRI

1. Non-ionising, for they do not use X-ray as medium for imaging.
2. Multiplanar imaging is automatically possible, for images in sagittal, coronal and transverse planes are generated simultaneously.
3. Superior contrast in tissue give exquisite anatomical details.

4. Certain tissue diagnosis is possible, e.g. lipoma, edema, age of hemorrhage, etc.
5. MR myelogram is created without injection of any contrast medium.
6. In tumor imaging, it gives exact anatomical details regarding the tumor limits, edema limits, vascularity, etc.

CHAPTER

2

Relevant Anatomy

The vertebrae are connected by a series of longitudinally oriented ligaments. The most important ligament from a clinical perspective is the posterior longitudinal ligament, which connects to the vertebral bodies and posterior aspect of the vertebral disc and forms the anterior wall of the spinal canal. The ligamentum flavum, attaches between the lamina of the vertebra and attaches to the pedicles above and below, forming the posterior wall of the spinal canal and part of the roof of the lateral foramina through which the nerve roots pass.

Posterior longitudinal ligament runs from the second cervical vertebra to sacrum along the posterior surface of vertebrae and discs. The posterior longitudinal ligament is closely adherent to and blends with annulus fibrosus of the discs and adjacent margins of the vertebral bodies. At the mid-vertebral levels, the ligament is separated from the vertebral margins by 1–2 mm gap that is filled with connective tissue and venous plexus. The posterior longitudinal ligament has two strata of fibers—superficial and deep part.

The intervertebral disc is made up of an outer annulus fibrosis and a central nucleus pulposus. It is attached to the vertebral bodies above and below the disc by the superior and inferior endplates. The nucleus pulposus is a gel-like substance made up of a meshwork of collagen fibrils suspended in a mucopolysaccharide base. It has a high water content in young individuals, which gradually diminishes with degenerative changes and with the natural aging process. The nucleus merges with the surrounding capsule, the collagenous annulus fibrosus. The annulus fibrosis is made

up of a series of concentric fibrocartilaginous lamellae which run at an oblique angle of about 30º orientation to the plane of the disc. The fibers of adjacent lamellae have similar arrangements, but run in opposite directions. The fibers of the outer annulus lamella attach to the vertebral body and mingle with the periosteal fibers. The fibrocartilaginous endplates are made up of hyaline cartilage and attach to the subchondral bone plate of the vertebral bodies. The cartilaginous end plate fuses the inferior and superior surfaces of the vertebral body to the disc. There are multiple small vascular perforations in the endplate, which allow nutrition to pass to the disc.

The three major components of the intervertebral disc are the nucleus pulposus, the annulus fibrosus, and the endplate. The components of the disc complex optimize shock absorption from mechanical stresses on the vertebral column. Anatomically the disc space is defined, superiorly and inferiorly, by the vertebral body endplates and peripherally, by the outer edges of the vertebral ring apophyses.

The spinal canal contains and protects the spinal cord and the spinal nerves. The spinal cord originates at the foramen magnum and extends to the conus medullaris, which terminates at the L1–L2 vertebral body junction in adults. The spinal cord projects distally through the spinal canal from the brain, to taper out at the lower first or upper second lumbar vertebral level. The lower level of the spinal cord is known as the conus medullaris, from which nerve roots descend through the spinal canal to their respective exit points, in the form of cauda equina. The spinal cord

is ensheathed by the three layers of the meninges. The pia mater invests the conus medullaris and rootlets. The pia mater condenses caudally to this area, extending to the sacrum as the filum terminale. The outer layer, or dura mater, is separated by a potential subdural space to the arachnoid meninges. The subarachnoid space, which separates it from the pia mater, is filled with cerebrospinal fluid, which circulates up and down the spinal canal. The dura mater and pia mater continue distally, ensheathing the spinal nerves to the exit points. The ventral and dorsal nerve roots join to form the spinal nerve which exits the spinal canal. At every vertebral level paired ventral and dorsal nerve roots exit the lateral aspect of the cord and coalesce to form 31 (thirty one) pairs of spinal nerves. The nerve roots, as they exit through the foramen, can be best seen on MRI scan and the size of the nerve root canal, which has the potential to entrap these nerves, can be measured.

The lumbar spine has an average of 5 vertebrae (normal range 4–6), with an intervertebral disc interposed between adjacent vertebral bodies. A cartilaginous endplate exists between the disc and the adjacent vertebral bodies and is considered part of the disc. If L5 vertebra has features of a sacral vertebra, then it is called sacralization of lumbar vertebra. For example, the transverse processes of L5 may be long, fuse with the ilium, thus becoming sacralised. If S1 vertebra has features of a lumbar vertebra, then it is called lumbarisation of a sacral vertebra. This anatomic variation may sometimes be responsible for entrapment neuropathy and can also contribute to low backache.

CHAPTER

3

Normal MRI of Lumbar Spine

- MRI is considered the best single imaging modality of the spine for its ability to demonstrate all of the spinal components—bone, discs, ligaments, fatty tissue, dura, CSF, neural tissue, and blood vessels—with superb contrast resolution.
- Basically in T1W images the CSF appears dark, while in T2W images the CSF appears white, due to high water content.
- Cortical bone contain scarce water molecules and therefore scarce free hydrogen protons. Hence present as a very low signal element on the MR image and therefore appear black in the image produced.
- The medullary bone has higher intensity in both T1- and T2-weighted images as compared with the cortical bone.
- The fibrous compact tissue of the outer annulus and the Sharpey's fibres have a low signal (dark) on both T1- and T2W, whereas the nucleus pulposus, composed of fibrocartilaginous tissue with a mucoid matrix, has a high signal (white) intensity on T2W. In T1W image normal discs appear homogenous and the nucleus and annulus cannot be differentiated.
- On axial sections, the roots of the filum terminale typically lie in a symmetric, crescent-shaped pattern with the lower sacral roots positioned dorsally and the lumbar roots positioned more anterolaterally. The most laterally positioned roots at each level are those about to exit the dural sac and pass through the intervertebral foramen. On T2- weighted images they look dark against the

high-signal CSF, whereas on T1-weighted images they have moderate signal intensity and look gray as compared with the dark CSF.

- Using heavily T2-weighted sequences results in MR "myelography effect" thus providing detailed definition of the thecal margins, nerve roots, and root sheaths and CSF spaces.
- Sagittal T1- and T2-weighted images provide a good overview of the spinal structures.
- In T1-weighted images, however, the contrast between the discs, bone marrow, dural sac, CSF, and nerve roots is not as good as in T2-weighted images.
- The T2W images, in which the CSF is bright, provides a clearer background for the nerve roots and discs. In T2-weighted images of normal discs, the nucleus has a much brighter signal and can be easily differentiated from the darker annulus and the darker cortical bone. The spinal cord appears as a dark gray structure on T2 and is brighter than the CSF
- Intravenous. contrast agent is used to differentiate postoperative epidural scarring (which enhances) from recurrent disc herniation (which does not) and to characterize intraspinal tumors. The contrast agent used in MRI is Gadolinium-DTPA. The contrast studies are usually done in T1W images.

NORMAL DISC

On MRI, the normal adult disc presents an intermediate to low signal intensity on T1-weighted images and a high

signal intensity on T2-weighted images, when compared to the bone marrow in the adjacent vertebral bodies. On T2-weighted scans the normal bright nucleus pulposus and the inner annulus are indistinguishable. The outer annulus, which contains densely packed fibers, is hypointense on all MR pulse sequences and is optimally demonstrated on T2-weighted images.

CHAPTER 4

MR Examination of Lumbar Spine

Magnetic resonance (MR) of the lumbar spine is performed in the sagittal, coronal and axial planes. The sagittal examination provides information on vertebral alignment and integrity of the vertebral bodies pars interarticularis and a general overview of the thecal sac, cauda equina, and nerve roots. The nerve roots within the neural foramina are well visualized on sagittal images. The overall marrow signal is also best evaluated in this plane. The grading of spondylolisthesis is best made in sagittal plane. Any abnormality on sagittal views should be confirmed on axial views and vice versa. The axial view confirms the findings of sagittal view and gives information about the spinal canal dimensions and what causes the narrowing, e.g. disc, synovial cyst, ligamentous hypertrophy or intraspinal tumours. The degree of spinal thecal sac cord compression is best shown in axial plane. T1-weighted images provide the best anatomic information because the bright epidural fat outlines the normal, darker structures of the spine and spinal canal. T1-weighted images provide optimal contrast between these structures. Moreover, because vertebral marrow has a significant amount of fat, the osseous anatomy is well visualised on T1 sequences, any infiltrative pathology of the marrow (e.g. a neoplasm) can be seen as abnormally low signal within the bright vertebral fat.

On T1-weighted images, bone is of intermediate to high signal intensity, depending on the degree of fatty marrow. Low signal intensity in bone suggests pathologic infiltration. and high signal suggests osteoporosis. Discs reflect intermediate signal intensity. The nerve roots, which also

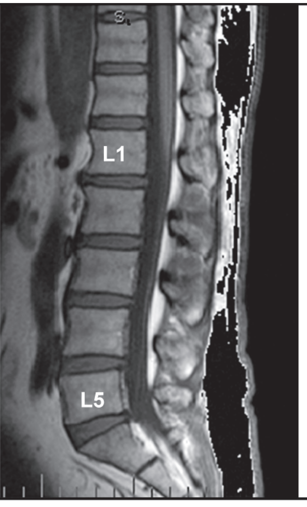
reflect intermediate signal intensity, are surrounded by low-signal-intensity CSF, which in turn is enveloped by high-signal fat. On T1-weighted images, ligamentum flavum reflects intermediate-to low-signal intensity.

T2-weighted images optimize contrast between disc, bone, and CSF. T2-weighted images make the CSF “myelographically” bright and the bone darker, which helps reveal the effects of osteophytes and bony hypertrophy on the thecal sac. The physician should pay careful attention to both T1-weighted and T2-weighted sequences when analyzing the images.

On T1-weighted MR images, the disc is a fairly homogeneous structure, isointense to muscle. On T2-weighted images, the disc becomes brighter because of its water content, the nucleus pulposus, which is more hydrated than the annulus fibrosus, becomes even brighter than the annulus.

The sagittal plane should include the conus down to at least the level of S1 level.

NORMAL LUMBAR SPINE



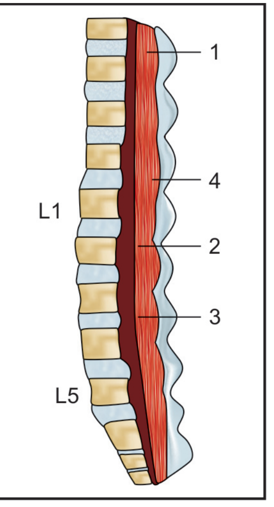


FIG. 4.1: T1W SAGITTAL

T1W Sagittal view of lumbar spine shows the normal alignment, dark CSF, grey spinal cord ending at lower border of L 1 vertebra. The disc does not show any difference in signal intensity between the central nucleus pulposus and peripheral annulus fibrosus

1. Spinal cord
2. Conus medullaris
3. Thecal sac
4. Epidural space

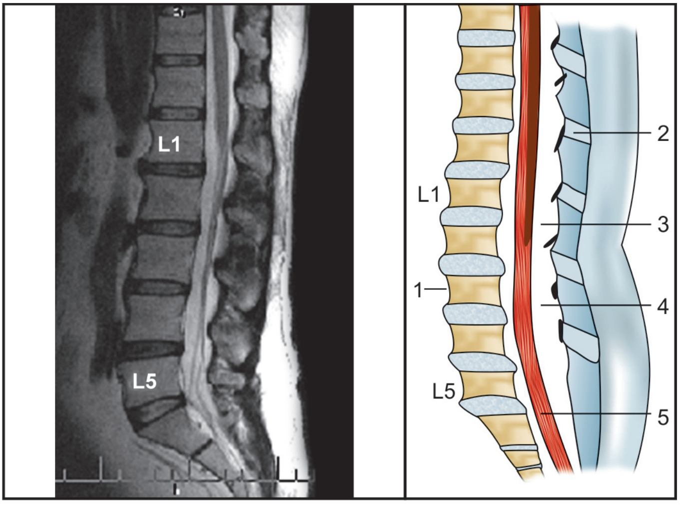


FIG. 4.2: T2W SAGITTAL

T2W sagittal view clearly shows the spinal cord with white CSF background. Note also the disc showing the central bright (hyperintense) nucleus pulposus and peripherally darker (hypointense) annulus fibrosus. Conus medullaris, cauda equina, etc. are well delineated

1. Vertebral boby
2 Ligamentum flavum
3. Conus medullaris
4. Spinal canal
5. Thecal sac

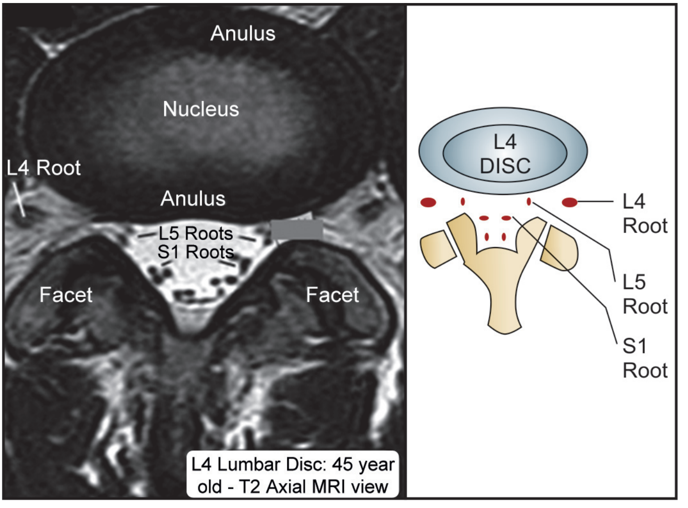


FIG. 4.3: T2W-TRANSVERSE (AXIAL)

T2W transverse (axial) view at L4 disc level shows the signal intensity difference between central nucleus pulposus and darker annulusfibrosus. Note the cauda equina nerve roots floating in bright CSF Intensities. Note the facet joint, neural exit foramen where the L4 nerve root exits

At the L4 disc level note the orientation of nerve roots in a definite fashion—L4 root at the top and S1 root at bottom and L5 root in the midway

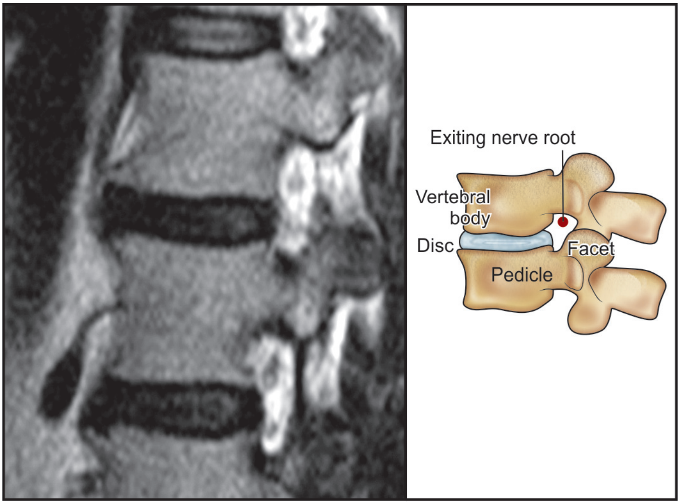


FIG. 4.4: T2W PARASAGITTAL (OBLIQUE) VIEW

The image shows the intervertebral foramen through which the nerve root is exiting. The oval shaped intervertebral foramen has the nerve root exiting at the superior level

At any given level, the nerve root of a particular vertebra exits higher up than corresponding disc level. Therefore any disc herniation will not affect the corresponding nerve root, but a nerve root lower than the herniated disc level. For example the L4 disc herniation will compress L5 root and not L4 root

NORMAL MR MYELOGRAPHY

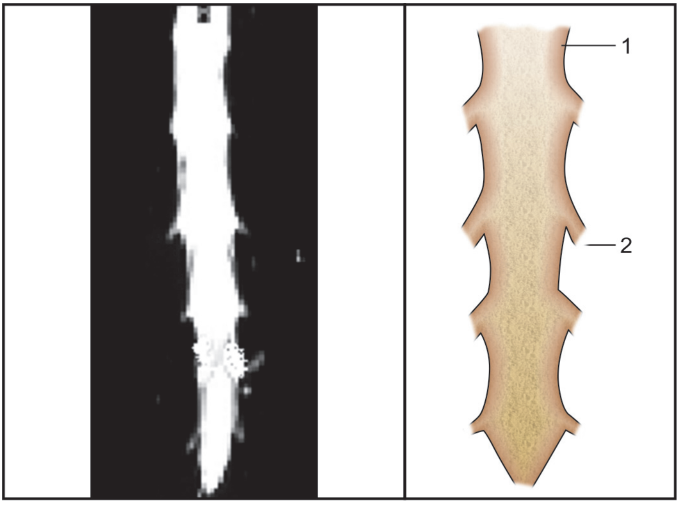


Fig. 4.5A: CORONAL PLANE

1. Spinal thecal sac
2. Nerve root sheath

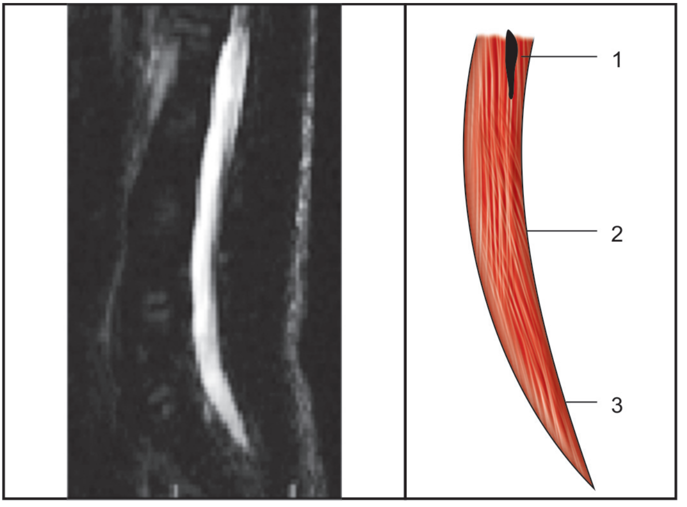


Fig. 4.5B: SAGITTAL PLANE

1. Conus medullaris
2. Nerve root in cauda equina
3. Spinal thecal sac

Note-

The high water content of CSF gives bright signals in this T2W sequence, giving a myelographic effect. MR myelogram can be seen in all three planes-sagittal, coronal and transverse. Note the exiting nerve root carrying a sheath of CSF along with them. Note the centrally placed conus medullaris and cauda equina branches extending from the the conus.

CHAPTER

5

Lumbar Spinal Diseases

LUMBAR SPONDYLOSIS

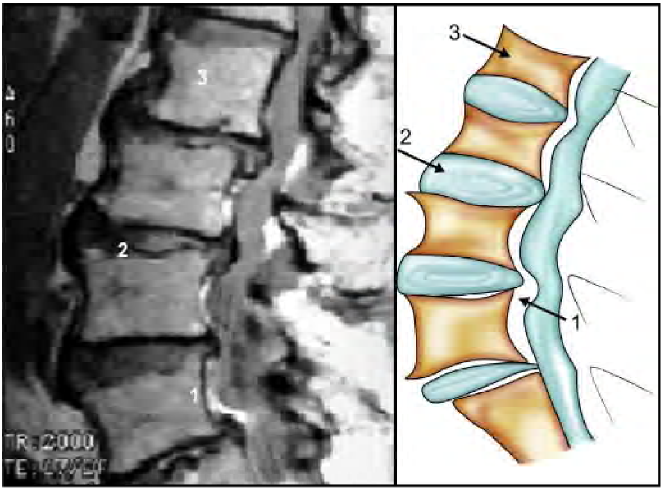


FIG. 5.1: T1W SAGITTAL

Sagittal image demonstrates multiple levels spondylotic changes and central canal stenosis at L2–L3 and L3–L4 levels. Note the multiple osteophytes, disc degeneration, changes in vertebral body size, signal intensity

1. Posterior marginal osteophyte
2. Degenerated disc
3. Reduced vertebral height

DISCUSSION

Spondylosis is a term referring to degenerative arthrosis of the joints between the bodies of the spinal vertebrae and/or neural foraminae. In this condition the interfacetal joints are not involved. If severe, it may cause pressure on nerve roots with subsequent sensory and/or motor disturbances, such as pain, paresthesia, or muscle weakness

in the limbs. Lumbar spondylosis encompasses lumbar disc bulges, herniations, facet joint degeneration, and vertebral bony overgrowths (osteophytes). Lumbar spondylosis, describes bony overgrowths (osteophytes), predominantly those at the anterior, lateral, and, less commonly, posterior aspects of the superior and inferior margins of vertebral bodies. This dynamic process increases with, and is perhaps an inevitable concomitant, of age. Lumbar spondylosis is present in 27–37% of the asymptomatic population. Lumbar spondylosis appears to be a nonspecific aging phenomenon. Spondylotic osteophytes occurs as a result of new bone formation in areas where the anular ligament is stressed due to constant wear and tear. Note the direction, size and orientation of osteophytes which help in distinguishing them from syndesmophytes, which are classically seen in ankylosing spondylosis. Spondylosis can also take the form of marginal end plate osteophytes, enlarged uncinate processes, or facet arthrosis. Degenerative joint disease itself, along with associated inflammatory reaction, can cause pain, or the symptoms can be derived from the osteophytes compressing neural structures. It is important to distinguish spondylosis from disk disease for therapeutic planning.

SPONDYLOLISTHESIS

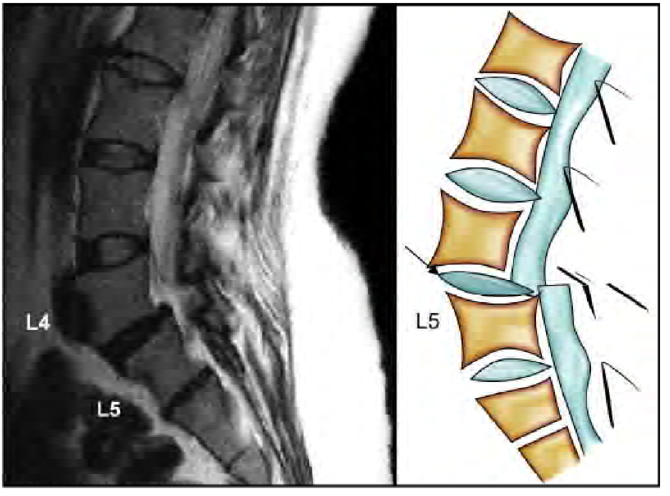


FIG. 5.2: T2W SAGITTAL

MR image shows anterior subluxation of L4 body over L5 body. There is disruption of anterior and posterior longitudinal ligaments. Note the degeneration of disc also. There was evidence of bifacetal dislocation on other images. This is also known as antero-listhesis

The blue arrow points to the spondylolisthesis. Note also the L4/L5 disc degeneration

DISCUSSION

Spondylolisthesis is the forward slippage of one vertebral body on another. This most commonly occurs at the lumbosacral junction with L5 slipping over S1, but it can occur at higher levels as well. The etiology of spondylolisthesis is multifactorial, with a hereditary

disposition combined with forces of posture, gravity and rotational forces. Six types of spondylolisthesis are classified according to etiology: dysplastic or congenital, isthmic, degenerative, traumatic, pathologic, and iatrogenic. The amount of vertebral subluxation is graded (Based on how far the vertebral body moves forward on the one below). According to Meyerding: Grade 1-slippage of less than 25% of the vertebral diameter, Grade 2 is 25–50%, Grade 3 is 50–75%, Grade 4 is 75–100% and spondyloptosis is greater than 100% subluxation. The instability of the spine can lead to back pain, radiculopathy, and neurogenic claudication. Common types of spondylolisthesis are: isthmic (open arch type) and degenerative (closed arch type).

Findings

- Degenerative spondylolisthesis: narrows spinal canal, usually occurs at L4–L5 level; degenerative facet joint disease, synovial cyst may be seen.
- Isthmic spondylolisthesis: elongates spinal canal (wide canal sign) in its anteroposterior dimension; discontinuity of pars interarticularis, typically at L5 seen.
- "Kissing spines": apposition of adjacent spinous processes due to hyperlordosis.
- On axial views, horizontal line (extra joint) between adjacent facets joints on consecutive images is the key observation. Axial images are best for displaying abnormal facets and ligamentum flavum and for assessing the degree of spinal stenosis.

- Sagittal plane is best for displaying abnormal anatomy of spondylolisthesis, T2-weighted images for the canal, and T1-weighted images for the pars interarticularis and neural foramina. Sagittal view clearly shows the degree of subluxation and relationship of intervertebral disc to adjacent vertebral bodies and spinal canal.
- Parasagittal images are good for showing foraminal encroachment by disc or hypertrophic bone.
- Coronal or oblique views effectively display the course of nerve roots.

SPONDYLOLYSIS

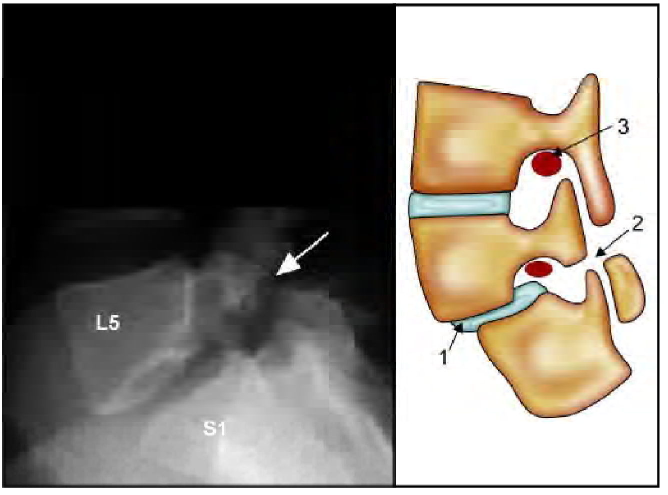


FIG. 5.3: CONVENTIONAL X-RAY LATERAL

The yellow arrow points to the defect in the pars interarticularis, causing subluxation of L5 vertebra over S1. There is a grade 1 spondylolisthesis

1. Anterior subluxation of L5
2. Defect in pars interarticularis
3. L4 nerve root in intervertebral foramen

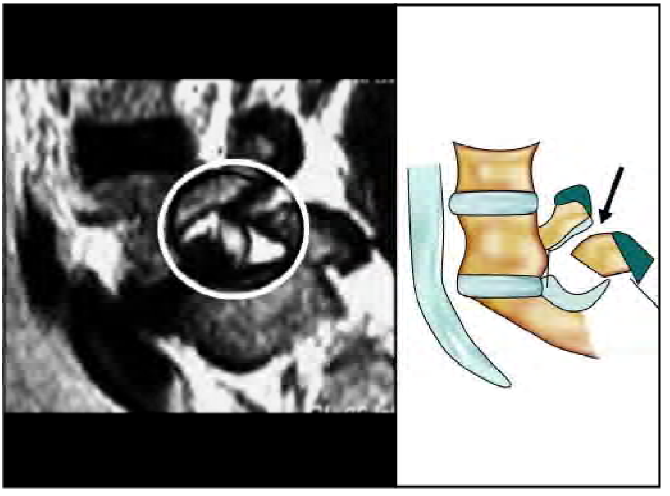


FIG. 5.4: PARASAGITTAL (OBLIQUE) T2W VIEW

The yellow circle shows the defect in the pars interarticularis

The blue arrow points to the pars interarticularis

Right and left parasagittal MR of lumbar spine at the level of the neural foramina showed bilateral defects and widening of the L5 pars interarticularis (neck of the scottie dog). Again the L5 spondylolisthesis is appreciated. The neural foramina are mildly narrowed, bilaterally.

DISCUSSION

Pars interarticularis defect (also called spondylolysis), which consists of an interruption of the vertebral arch at the bony bridge that holds together the superior and inferior processes (pars interarticularis). Spondylolysis is a defect in the pars interarticularis, which is the weakest portion of the vertebrae. Ninety percent of pars defects occur at the L5 level, less

commonly at L4 and L3 levels. Elongation of the pars is thought to be due to repetitive microfractures with subsequent healing in an elongated position. Athletes in gymnastics, soccer, tennis, baseball, football, and wrestling are more likely to have symptomatic spondylolysis at some point. When the defects are bilateral, spondylolisthesis may occur. Pars visualisation can be difficult on MR because degenerative facet disease is often associated with loss of marrow signal and sclerosis of pars interarticularis.

Next to disc herniation, this is the common cause of low backache. The spondylolytic (isthmic) type is the most common cause of spondylolisthesis. It affects the region of the pars interarticularis, which is roughly the region of the junction of the pedicle and lamina, where the articular and transverse processes of the vertebrae arise. A defect at this point functionally separates the vertebral body, pedicle, and superior articular process from the inferior articular process and remainder of the vertebrae. Thus, the defect cleaves the vertebra into 2 parts The portion of the vertebra posterior to the defect remains fixed, and the anterior portions are free to potentially slip forward relative to the posterior structures and spine below. Note that bilateral pars defects are needed to allow slippage.

Spondylolysis is a fibrous cleft within the pars interarticularis. Incidence is 5% in the general population. It occurs at any age. Etiology is debated as either congenital or acquired from trauma or repetitive high impact excercise.

When both pars interarticularis are disrupted the affected vertebra is free to anteriorly sublux (spondylolisthesis) since

the normal facet joint is separated from the vertebral body. This leads to varying degrees of anterior-posterior opening or enlargement of the spinal canal at that level. Plain films, or in this case, CT shows radiolucent defects in the pars interarticularis, commonly bilaterally. Neural foramina are distorted and narrow variably, partly due to bony proliferation around the pars defects as well as the subluxation and eventually disc degeneration. The facet joints stay intact. The intervertebral disc usually bulges but does not herniate, and then will degenerate.

DISC DEGENERATION

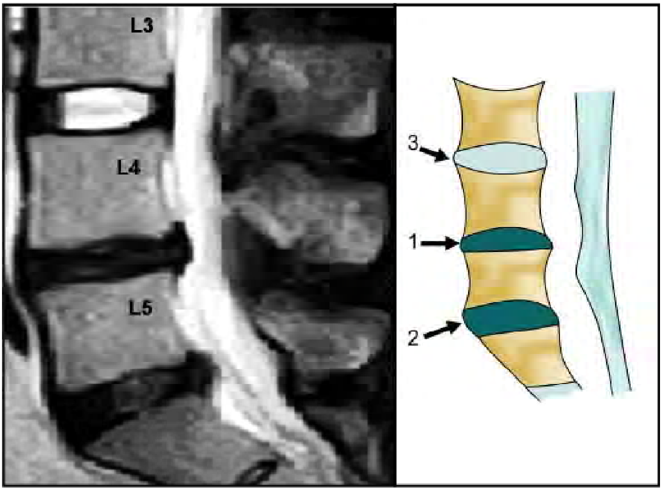


FIG. 5.5: T2W SAGITTAL

The image shows dark signals in L4/L5 and L5/S1 disc indicating degeneration
Note the normal signal from L3 /L4 disc

1. Degenerated L4/L5 disc
2. Degenerated L5/S1 disc
3. Normal L3/L4 disc

DISCUSSION

MRI is the method of choice to detect early signs of intervertebral disc degeneration. The concept of degeneration encompasses changes involving the disc (desiccation, fibrosis, annular tears, mucinous degeneration of the annulus, loss of height), as well as the endplates (defects, sclerosis, osteophytic spurring at the apophyses, modic changes). Narrowing of the disc space, diffuse bulging of the anulus

beyond the disc space, vertebral endplate changes, and osteophytes at the vertebral apophyses are the features of disc degeneration. Signal loss on T2-weighted scans is an early indicator of intervertebral disc degeneration on MRI. The degenerative process typically starts at the intervertebral discs that are subjected to the greatest mechanical stress in terms of weight-bearing or motion. In the lumbar spine L5–S1 and L4–L5 are most commonly affected segments because they bear the brunt of marked spine motion. The bright signal intensity of the normal intervertebral discs on T2-weighted images gradually decreases, until the discs become hypointense. T2-weighted scans are best suited for detecting degenerative discs. The loss of signal intensity is concomitant with a decrease in water and proteoglycan content, and an increase in collagen in the disc.

With aging, the disc undergoes a process of desiccation: the nucleus pulposus dries, becomes less elastic, and the amount of collagen in the disc increases. Changes in a disc is related to aging. The term degenerated disc, in itself, does not infer knowledge of cause, relationship to aging, presence of symptoms, or need for treatment.

One of the earliest signs of disc degeneration is loss of water content or desiccation, most noticeable in the nucleus pulposus. MR can detect early disc degeneration because, as the discs lose water, the MR signal decreases on T2-weighted images. With more advanced degeneration, the disc collapses and gas may form within the disc. Calcification is not uncommon in chronic degenerative disc disease but cannot be studied by MR imaging.

DISC BULGING

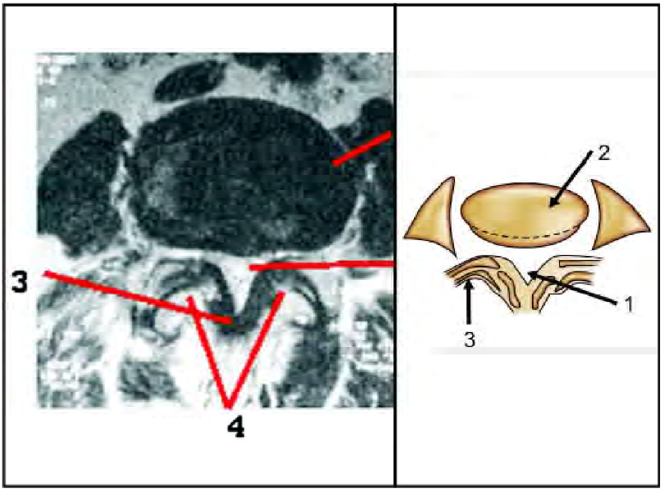
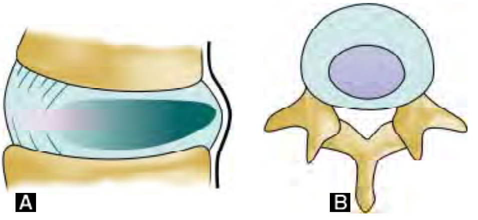


FIG. 5.6: T2W AXIAL

1. Bulging disc
2. Spinal canal narrowed
3. Facet joint
4. Spinal stenosis

1. Ligamentum flavum
2. Bulging disc
3. Ligamentum flavum thickened

Note: The normal disc outline shown by dotted line this may contribute to the disc is bulging beyond the outlines of vertebral body.



FIGS 5.7A AND B: (A) INTACT POSTERIOR LONGITUDINAL LIGAMENT AND; (B) CONVEX DISC MARGIN

DISCUSSION

As a consequence of intervertebral disc degeneration, normal axial loading on the spine stretches and lengthens the anular fibers, resulting in rounded, symmetric bulging of the disc beyond the margins of the vertebral body. A bulging disc encroaches on the ventral spinal canal and inferior portions of the neural foramina but does not displace or impinge the nerve roots. The combination of sagittal and axial views provides excellent visualisation of the relationships of the disc to the spinal canal and neural foramina. When there is a generalised paucity of epidural fat, producing an MR "myelogram" with gradient-echo or T2-weighted images are helpful to show the relationship of the disc with the thecal sac.

A bulging disc is not a herniation. Generalised or circumferential disc displacement (involving 50% to 100% of the disc circumference) is known as "bulging", and is not considered a form of herniation. Disc bulging is very common with diffuse enlargement of disc area. It may contribute to

spinal stenosis. It is usually not clinically significant. Bulging discs may be symmetrical or asymmetrical.

An *annular bulge* represents an extension of the disc margin beyond the confines of the adjacent vertebral end plate. The annular fibers are stretched but intact. The disc bulges diffusely around the posterior (and sometimes lateral) aspects of the endplate. This does not usually lead to clinical symptoms unless the spinal canal is already congenitally small or narrow owing to spondylosis.

Bulging has been variously ascribed to redundancy of annulus secondary to loss of disc space height, ligamentous laxity, response to loading or angular motion, remodeling in response to adjacent pathology, unrecognized and atypical herniation. Bulging may or may not represent pathologic change, physiologic variant, or normalcy.

ANNULAR TEAR (Example 1)

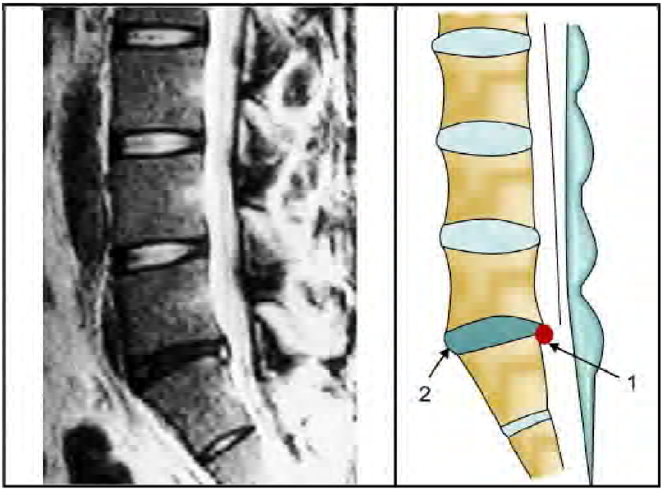
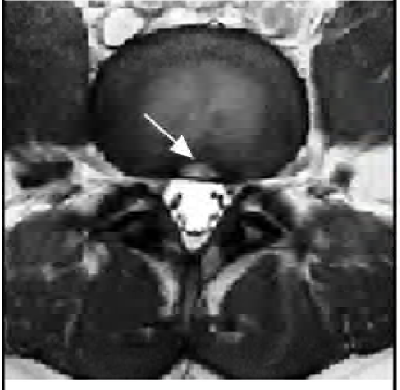


FIG. 5.8: T2W SAGITTAL

The image shows L5/S1 disc degeneration with an annular tear, shown by an hyperintense focus. Note the L5/S1 disc showing degeneration in the form of reduced height, decreased signal intensity. This degenerating disc shows a peripherally placed annular tear as evidenced by a small bright dot in the posterior disc margin. This tear recognition is important because it is the forerunner of frank disc prolapse. Note the normal size and signal intensities in rest of the normal discs

1. Hyperintense focus corresponding to the annular tear
2. Degenerated disc

ANNULAR TEAR



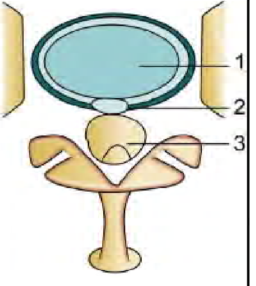


FIG. 5.9: T2W TRANSVERSE

Yellow line points to focal white signal in disc periphery

1. Disc
2. Annular tear (small white circle)
3. Cauda equina

ANNULAR TEAR (Example 2)

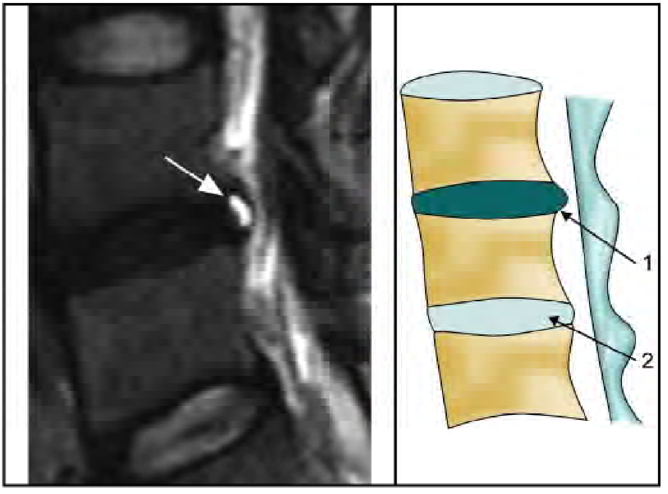


FIG. 5.10: T2W SAGITTAL

White arrow points to the annular tear and also note the disc degeneration

1. Annular tear
2. Normal disc

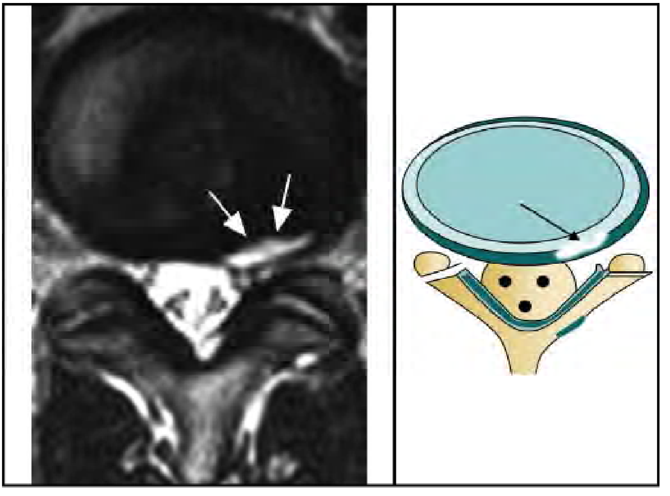


FIG. 5.11: T2W AXIAL

Transverse T2-weighted images through L4–5 disc space. Note high signal intensity (bright white) in the outer annulus and/or posterior longitudinal ligament complex iwhich represents area of annular disruption

Blue arrow points to the site of annular tear

DISCUSSION

With increasing age the intervertebral disc becomes less elastic and more fibrous. Eventually this leads to the formation of cracks and fissures in the annulus fibrosus, which are known as “annular tears”. Annular tears are separations between annular fibers, avulsion of fibers from their vertebral body insertions, or breaks through fibers that extend radially, transversely, or concentrically, involving one or many layers of the annular lamellae. The terms “tear”

or “fissure” describe the spectrum of such lesions and do not imply that the lesion is consequent to trauma. Some annular tears cause low back pain, even without modification of the disc contour. Complete radial tears predispose to extrusion of nuclear material. Annular tears are recognizable as areas of high signal intensity on T2-weighted images or as foci of annular contrast enhancement.

Annular tears are depicted on MR scans as small focal areas of hyperintensity on sagittal T2-weighted images. Transverse tears are located at the periphery of the annulus adjacent to the vertebral margins. Radial tears tend to be more irregular and obliquely oriented. High-signal- intensity zones on T2-weighted MR images are commonly seen along the posterior margin of degenerated discs in asymptomatic patients. The high-signal-intensity does not imply acute disc disruption, and no association with trauma has been proven.

Complete disruption of the annulus exposes the nuclear material to the epidural tissues, inducing a focal inflammatory reaction. Vascular granulation tissue forms and grows into the disc through the annular tear. Enhanced MR images will detect more annular tears than T1 or T2-weighted images alone—mostly radial tears, but also a few transverse tears

Herniation of the nucleus pulposus (HNP) through an annular defect causes focal protrusion of disc material beyond the vertebral endplate margin.

DISC HERNIATION

Significance

The determination of clinically significant disc disease is an important radiologic and clinical decision because the possible consequences of back surgery are not insignificant. Identification of nerve root compression or severe effacement of the thecal sac, especially ventrolaterally, that correlates with radicular pain or a muscle weakness pattern supports the operative approach when conservative medical therapy has failed. But beyond that, things are less certain. Annular tears and focal disc protrusions are frequently found in asymptomatic populations. The annuloligamentous complex is richly innervated by the recurrent meningeal nerve. Annular tears involving this complex may be a source of discogenic pain due to exposure of the nerve endings to the acid metabolites of the protruding nucleuspulposus. MR signs of intervertebral disc disease consisting of bulge, protrusion, or extrusion, etc. are seen in 64% of asymptomatic adult subjects. Moreover, disc herniation does not relate directly to back pain or a radicular pain syndrome. Lumbar disk herniations are found in 28% of asymptomatic patients over 40 years of age. Furthermore, all patients with symptomatic disc herniations do not necessarily require surgery. Patients with herniated lumbar discs for 6 to 15 months were under conservative medical therapy and on follow-up MR imaging, 63% showed a reduction in size of their herniated disc of more than 30%, 48% showed a reduction of more than 70%, and only 8% got worse

or enlarged. Larger herniations are more likely to decrease, which they attributed to more vascularity or granulation tissue.

Approximately 90% of lumbar disc herniations occur at L4–L5 or L5–S1. Over 90% occur within the spinal canal. These disc herniations may migrate superiorly or inferiorly from the disc space. While an attachment to the intervertebral disc remains, the material may be referred to as “extruded”. Disc material can also detach and migrate away from the parent disk and then has been referred to as a free fragment or sequestration. It is critical to diagnose these because failure to do so may lead to “Failed Back Syndrome”. The differential diagnosis of HNP includes neurofibroma, schwannoma, perineural cyst, onjoined nerve root, and dilated nerve root sleeve.

Disc Herniation—Terminology

Herniation (also known as prolapse) is defined as a localized displacement of disc material beyond the limits of the intervertebral disc space. Displacement of disc material can thus only occur when there is a disruption of the annulus fibrosus, or a break in the vertebral body endplate. The disc material may be nucleus, cartilage, fragmented apophyseal bone, annular tissue, or any combination thereof. Herniated discs can be more specifically classified as protrusion, extrusion, or sequestration on the basis of the shape and location of the displaced material. Bulges and protrusions are frequent in asymptomatic individuals, extrusions are not.

A disc in which the contour of the outer anulus extends, or appears to extend, in the horizontal (axial) plane beyond the edges of the disc space, over greater than 50% (180 degrees) of the circumference of the disc and usually less than 3 mm beyond the edges of the vertebral body apophyses is called a bulging disc.

The terminology "extruded disc" is used for a focal disc extension of which the base against the parent disc is narrower than the diameter of the extruded disc material, measured in the same plane. The nuclear material pushes beyond the posterior longitudinal ligament, but remains in contact with the parent disc. If the displaced disc material has no connection with the parent disc, it is called a "sequestrated fragment".

Disc nomenclature	Relation to parent disc	Depth of plane	Relation to posterior longitudinal ligament
Bulging	Present	All around disc	Intact
Herniation			
a) Protrusion	Present	Less than base	Sub-ligamentous
b) Extrusion	Present	More than base	Trans-ligamentous
c) Sequestration	Absent	Not relevant	Free, separate, beyond ligament

Chronic Disc Herniation

Disc herniation with presence of calcification, ossification, or gas accumulation within the displaced disc material, suggests that the herniation is not of recent origin. This term should not be used for herniations of soft disc material, regardless of the duration of displacement.

DISC HERNIATION—LOCATIONS

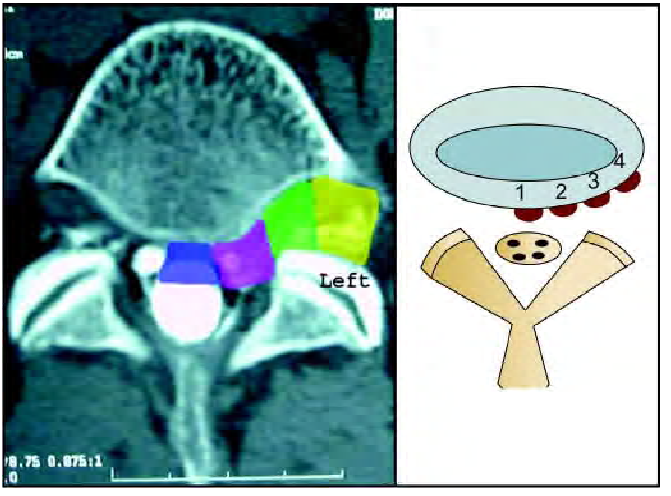


FIG. 5.12: T2W AXIAL IMAGE AND LINE DIAGRAM

In the Figure 5.11, T2W axial image and the corresponding line diagram

1. Blue — Central location
2. Pink — Paracentral/lateral recess location
3. Green — Intraforaminal/subarticular location
4. Yellow — Extraforaminal

BLUE: This is the 'Central Region' and is located directly behind the disc and encompasses the anterior aspect of the thecal sac. Since the PLL (posterior longitudinal ligament) is at its thickest in this region, the disc usually herniates slightly to the left or right of this central zone.

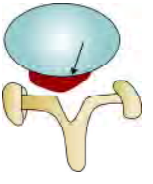
PINK: This is the ‘Paracentral Region’ or ‘Lateral Recess’ and is located just outside of the Central Region. Because the PLL is not as thick in this region, disc herniations are frequently found here; in fact, this is the number one region for disc herniations to occur in. The Traversing Nerve Roots, which are the neural structures found in this zone, are frequently contacted, deviated and compressed in this zone. (Remember, an L5 disc herniation that occur into the lateral recess with compress the traversing S1 nerve root, not the exiting L5 nerve root that is seen within the IVF.)

GREEN: This is the ‘Intraforaminal Zone’, also known as the ‘Subarticular Zone’, and is located within the intervertebral foramen (IVF). It is rare for a disc to herniate into this region or beyond; in fact, only 5% to 10% of all disc herniation occur here or farther out. This is because a super-delicate neural structure called the ‘Dorsal Root Ganglion’ (DRG) is seen in this zone. Any compression of the DRG can result in severe pain, sciatica (radiculopathy) and nerve cell body (neuron) damage.

YELLOW: This is the ‘extraforaminal zone’ and, as the name implies, is just outside (lateral to) of the IVF. Again, it is very rare for a disc to herniate into this region, a herniation in this zone may also irritate the ‘Sympathetic Nervous System’ and cause symptoms in the lower limb.

Blue	Central	Posterior to disc in midline	Less common
Pink	Paracentral or Lateral recess	Posterior to disc off midline	Most common
Green	Intraforamina, or foraminal	Intervertebral foramina	Classic Sciatica
Yellow	Extraforaminal or Far lateral	Lateral to intervertebral foramen	Very rare

DEGREES OF DISC HERNIATION INTO THE SPINAL CANAL

Degree of disc herniation	Involvement of spinal canal/ neural foramen (From axial images)	Green Colour – Disc Material
Mild	Less than 1/3	
Moderate	Between 1/3 to 2/3	
Severe	More than 2/3	

DISC HERNIATION AND NERVE ROOT COMPRESSION—GRADING

This is based on the relationship between herniated disc and the adjacent nerve root.

The most direct effect on the nerve root is from compression by the herniated disc, but the disc need not compress the nerve root directly to cause radicular pain. Fragments of nucleus pulposus within the epidural space induce a focal inflammatory reaction that can secondarily irritate the adjacent nerve root.

GRADE 0

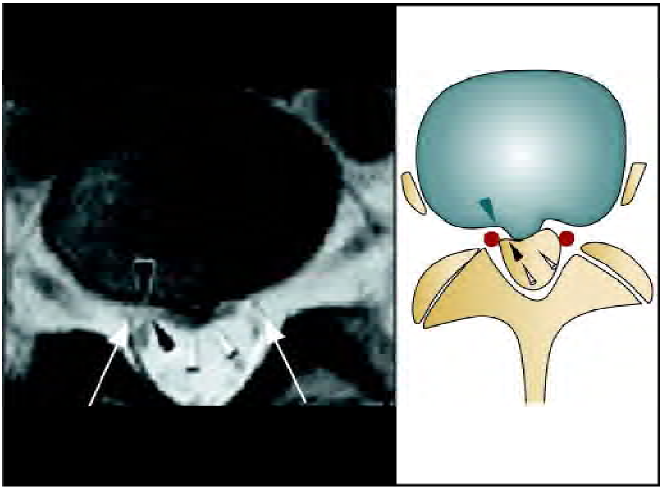


FIG. 5.13: T2W AXIAL

White arrow heads—Disc herniation
Black arrow heads—Epidural fat
White arrow—Nerve roots

NOTE

– There is no contact of herniated disc material with the adjacent nerve root.
– The epidural fat plane between disc material and the nerve root is preserved.

GRADE 1

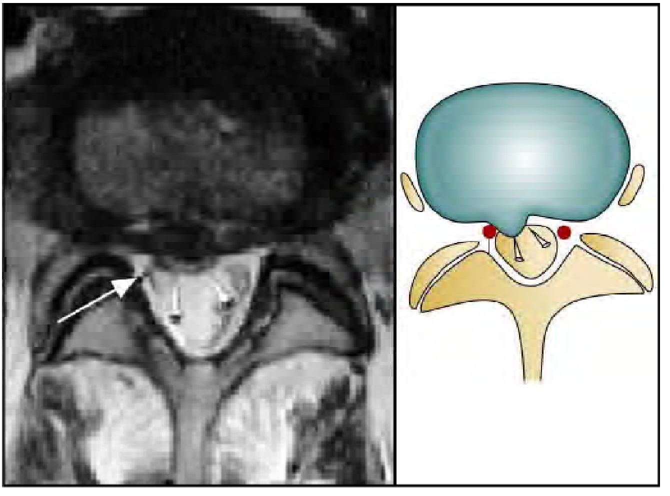


FIG. 5.14: T2W AXIAL

White arrow head—Disc herniation
White arrow—Normal nerve root

NOTE

- There is contact of prolapsed disc material with the adjacent nerve root.
- The loss of right side normal epidural fat plane between them.
- Note that the prolapsed disc material is only making contact with the nerve root and preserving the normal position of the nerve root.

GRADE 2

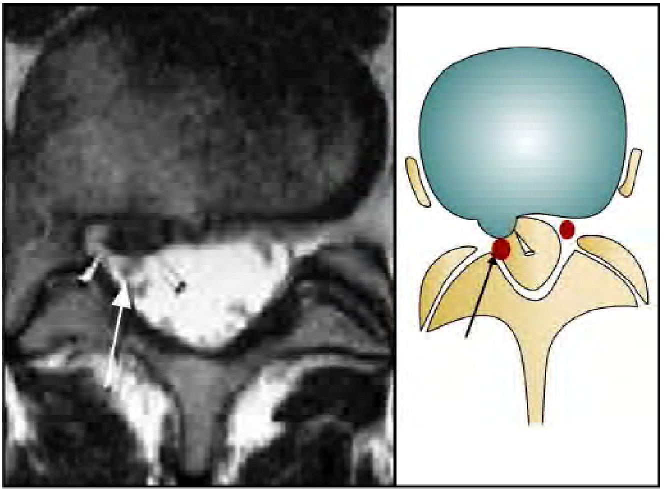


FIG. 5.15: T2W AXIAL
White arrow head—Disc herniation
White arrow—Displaced Nerve root

NOTE: The prolapsed disc material is displacing the adjacent nerve root in right side from its normal location.

GRADE 3

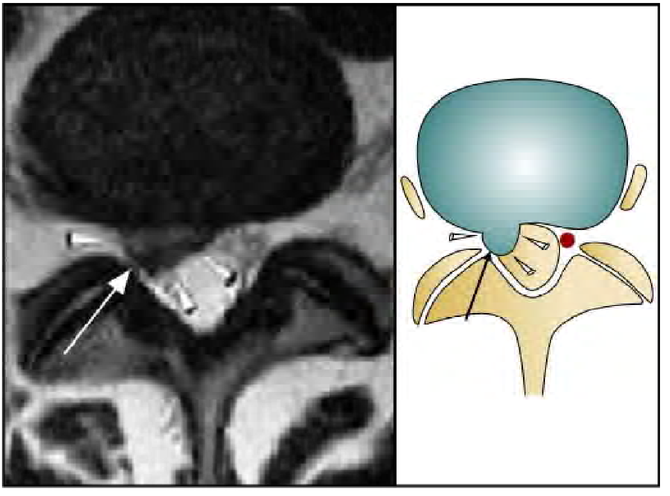


FIG. 5.16: T2W AXIAL
White arrow head—Disc herniation
White arrow—Displaced and compressed nerve root

NOTE:
- The nerve root is compressed between the prolapsed disc material and spinal canal wall.
- The compressed nerve root is flattened and becomes indistinguishable from the disc material.

DISC HERNIATION—PROTRUSION-CENTRAL (Example 1)

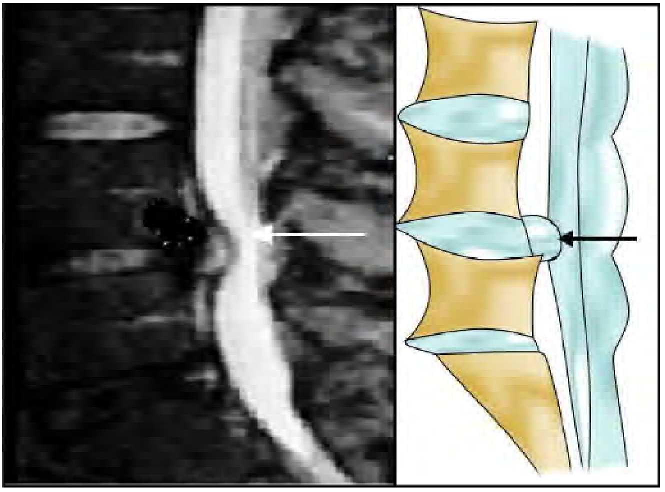


FIG. 5.17: T2W SAGITTAL

The yellow arrow shows the disc herniation disrupting the posterior longitudinal ligament

Blue arrow shows the disc herniation. It is not possible to differntiate central from other types disc herniation from sagittal view alone

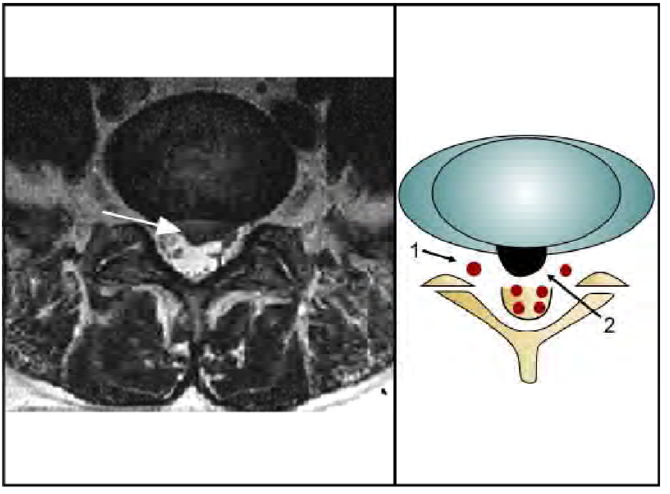


FIG. 5.18: T2W TRANSVERSE VIEW

The yellow arrow shows the central disc protrusion
Note the pressure effect on the thecal sac.

1. Nerve root
2. Central disc herniation 6 mm

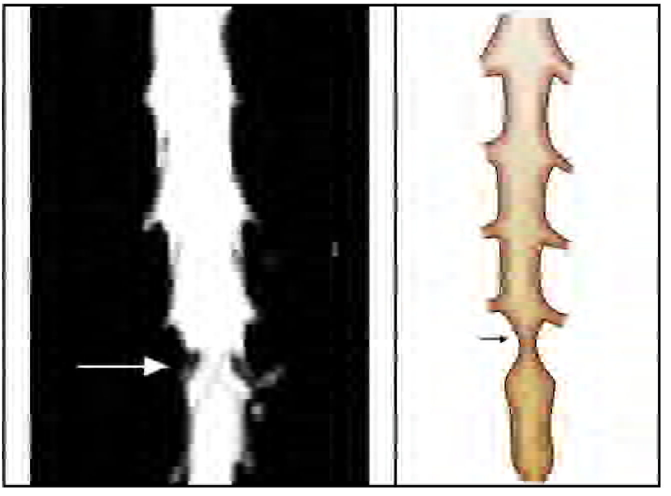


FIG. 5.19: MR MYELOGRAM—CORONAL

The yellow arrow in this image shows a waist like defect on either side due to central disc herniation

Blue arrow shows lateral indentation on either side of lateral border of myelography

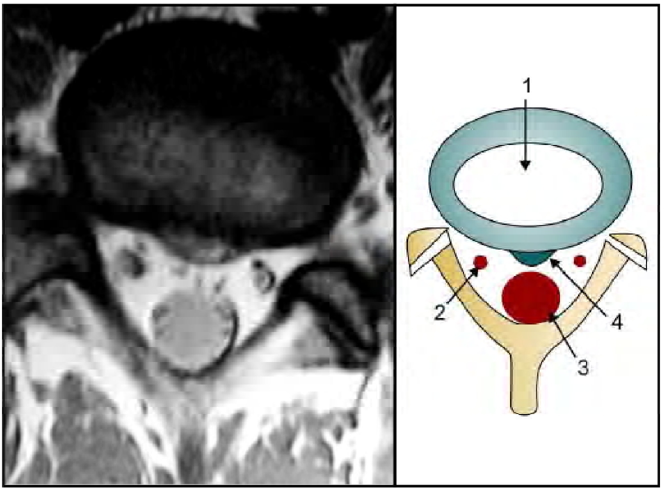


FIG. 5.20: T2W AXIAL IMAGE

The axial image shows a 4 mm central disc herniation
The thecal sac, nerve roots are intact

1. Degenerated L5 disc
2. Right S1 nerve root
3. Thecal sac
4. Central disc herniation 4 mm

DISCUSSION

The ‘Central Region’ is located directly behind the disc and encompasses the anterior aspect of the thecal sac. Since the PLL (posterior longitudinal ligament) is at its thickest in this region, the disc usually herniates slightly to the left or right of this central zone. In protrusion the nucleus pulposus pushes locally through fibres of annulus. The nucleus pulposus material may focally impinge on nerve roots and thecal sac, The terminology “protruded disc” is used when the base of the disc is broader than the apex or any other diameter of the displaced material. Based on the disc contour in the transverse plane, a protruded disc can be focal (involving < 25% of the disc circumference) or broad-based (involving 25–50% of the disc circumference), extending beyond 3 mm radius.

Any radial tear of the annulus is a potential site for herniation of the nucleus pulposus. On the sagittal view, dissection of nucleus pulposus through radial tears of the annulus is clearly depicted. Defects in the annulus with disc extending posteriorly are indicative of protrusion. In the sagittal plane, a herniated disc has an hourglass appearance along the posterior disc margin, which is described as a “squeezed toothpaste” effect. Axial scans show either asymmetry of the posterior disc margin or a soft-tissue mass displacing adjacent intraspinal structures.

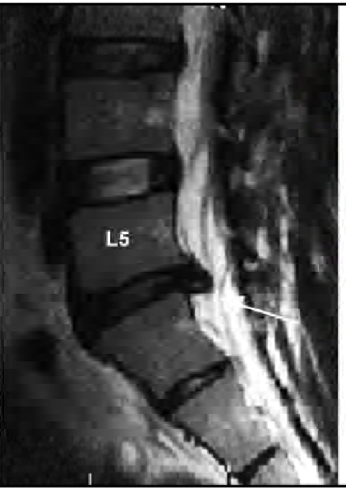
Most disc herniations occur in a posterolateral direction into the spinal canal because the tough posterior longitudinal ligament is thicker and tougher in the middle and resists posterior extension near the midline. A herniated disc usually

impinges on the nerve root as it courses inferiorly toward the foramen at the next lower level. For example, an L4-L5 herniated disc impinges on the L5 root. The L4 root is likely to be unaffected unless there is lateral and cephalad migration of a free fragment into the neural foramen.

The neural foramina are visualized on parasagittal images of the lumbar spine, and disc herniation can be detected by obliteration of foraminal fat. Nevertheless, axial MR is better for visualizing lateral disc herniations. Lateral discs compress the nerve root within the foramen or just beyond its lateral margin distal to the nerve root sheath.

In the lumbar region, there is marked enhancement, distinct from epidural venous plexus, surrounding disc herniations. Histology shows peridiscal scar tissue, similar to the epidural scar observed in postoperative patients. The depth of penetration of the scar depends on how long the disc fragment has been in the epidural space. The vascular scar tissue is a part of the body's repair mechanism to resorb and remove the offending disc material. Over time, the entire disc fragment may be resorbed.

DISC HERNIATION—PROTRUSION-POSTERO-LATERAL (Example 1)



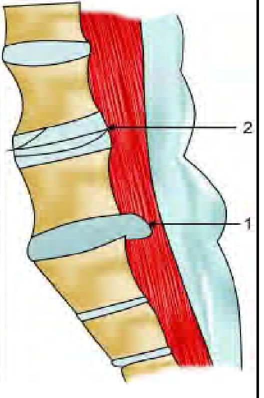


FIG. 5.21: T2W SAGITTAL

The yellow arrow shows L5/S1 disc herniation with indentation on the adjacent nerve root

1. Degenerated L5/S1 disc showing herniation
2. Normal L4/L5 disc

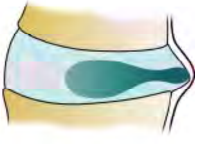


FIG. 5.22: DISC MATERIAL WHICH HERNIATES BEYOND THE VERTEBRAL MARGIN AND INDENTS THE POSTERIOR LONGITUDINAL LIGAMENT

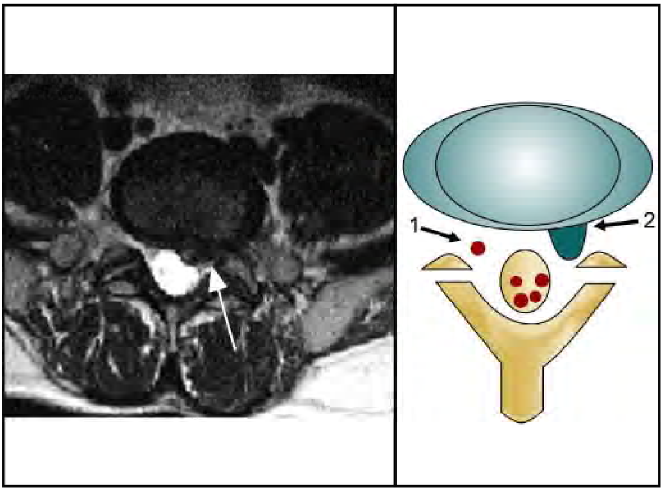


FIG. 5.23: T2W TRANSVERSE VIEW

In this image the yellow arrow shows posterolateral disc herniation compressing the nerve root in the left neural foramen

1. Normal nerve root in neural
2. Left posterolateral disc herniation obscuring the nerve root

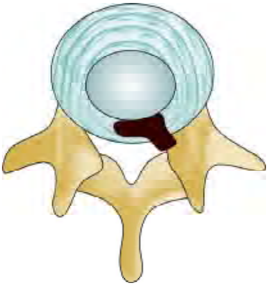


FIG. 5.24: LEFT FORAMINAL DISC HERNIATION (BLACK ARROW)

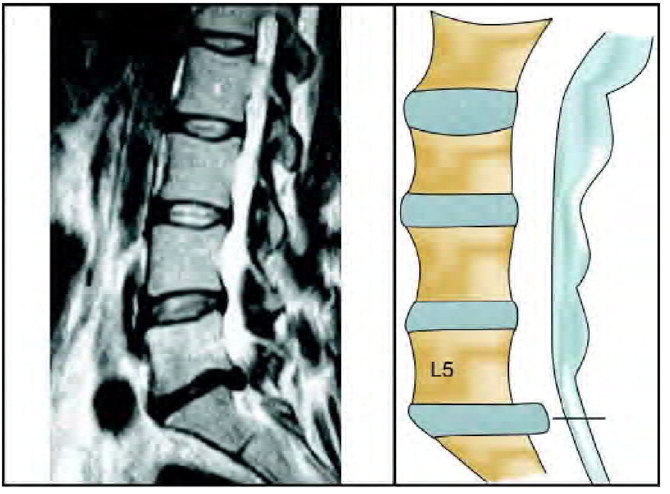


FIG. 5.25: T2W SAGITTAL IMAGE

L5/S1 disc showing degenerated disc with posterolateral herniation. From the sagittal view alone it is not possible to distinquish central from posterolateral herniations

The blue line points to the degenerated disc herniating posteriorly

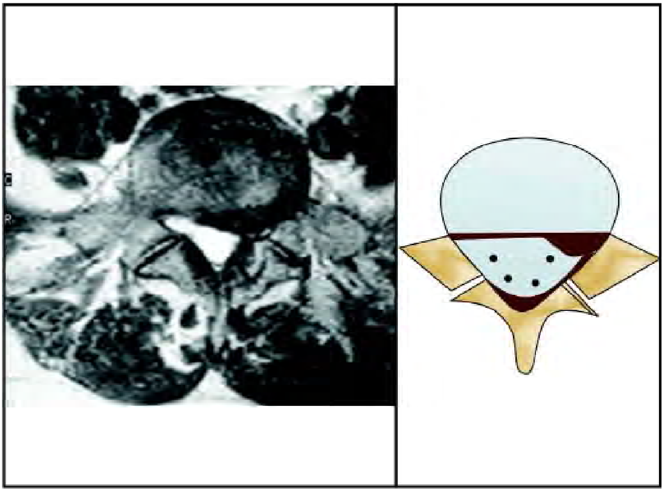


FIG. 5.26: T2W TRANSVERSE PLANE

There is left sided posterolateral disc herniation completely effacing the neural foramen

The blue line points to the left sided posterolateral disc herniation encroaching the neural foramen

DISCUSSION

In a protruded disc herniation, the disc materials are seen more than 3 mm in the anterior epidural space. The protrusion may be central, paracentral, foraminal or extraforaminal and it can be right or left side. This is the simplest type of disc herniation.

A specific type of disc herniation is the far lateral disc herniation (FLDH), also known as a foraminal disc herniation. FLDHs account for 3–10% of all disc herniations. In this situation, the herniated disc may cause nerve root compression within the foramin or extraforaminally, as the nerve root continues its extraforaminal course. They differ from classic, more medial herniations because FLDHs compress the exiting root at that level, whereas classic herniations compress the root at the level below. For example, an L4–5 FLDH will impinge upon the L4 root, while a classic herniation at L4–5 impinges upon the L5 root.

Most FLDHs occur in older individuals and originate from upper lumbar levels—the L3–4 and L4–5 discs. In contrast, classic disc herniations usually originate from the lower lumbar levels—the L4–5 and L5–S1 discs. Because of the anatomical location of FLDHs, their clinical presentation often differs from that of classic herniations. Classic herniations usually produce lower back pain and pain in the posterolateral thigh with radiation to the foot. On the other hand, FLDHs can cause sudden onset of pain in the anterolateral thigh. Additionally, the patient will likely have weakness in the quadriceps, decreased patellar reflex,

decreased sensation in the associated dermatome, and referred pain to the knee.

MR is helpful in differentiating a FLDH from a classic disc herniation as well as differentiating it from the other primary diagnosis on the differential—a schwannoma. On MR, FLDH appears as a protrusion that is contiguous with the intervertebral disc and will show peripheral contrast enhancement.

DISC HERNIATION—EXTRUSION

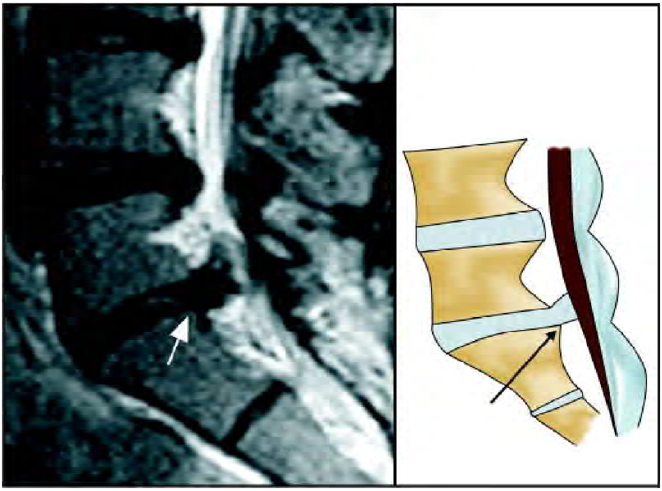


FIG. 5.27: T2W SAGITTAL

The disc material has a long plane in the spinal canal with a narrow neck and broad base. Note the continuity of herniated disc material with the parent disc

The blue arrow points to the extruded disc material at L5/S1 level

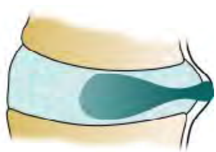


FIG. 5.28: DISC EXTRUSION IN THE SAGITTAL PLANE. NOTE THE NARROW NECK AND CONTINUITY WITH PARENT DISC

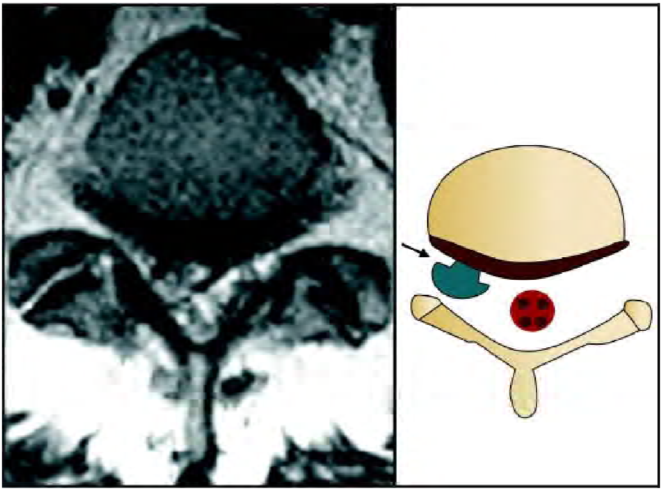


FIG. 5.29: T2W AXIAL

At L5–S1 disc space, the extruded disc herniations are characterized by a narrow neck than the base which is wider

The blue arrow points to narrow neck and broad base in the herniated disc material

FIG. 5.30: DISC EXTRUSION IN THE TRANSVERSE PLANE

DISCUSSION

The terminology "extruded disc" is used for a focal disc extension of which the base against the parent disc is narrower than the diameter of the extruded disc material, measured in the same plane. The disc material extends more than 3 mm. The nuclear material pushes beyond the posterior longitudinal ligament, but remains in contact with the parent disc.

A *disc extrusion* occurs when the nucleus pulposus herniates through a complete tear of the annulus fibrosus and remains attached to the parent disc but may extend cephalad or caudad. It can be difficult to differentiate between disc protrusion and extrusion when the amount of herniated disc is small. This distinction, however, is not clinically significant; it is more important to recognise that these are simply different degrees of herniation and that the significance of a herniated disc is its effect on the spinal canal and nerve roots.

DISC HERNIATION—SEQUESTRATION

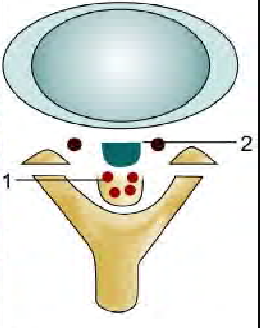


FIG. 5.31: T2W AXIAL

1. Indicates posteriorly displaced thecal sac
2. Yellow line 2 indicates disc fragment completely sequestrated from the parent disc and remaining in the spinal canal

1. Displaced thecal sac
2. Sequestrated disc

FIG. 5.32: SEQUESTRATED DISC IN AXIAL PLANE

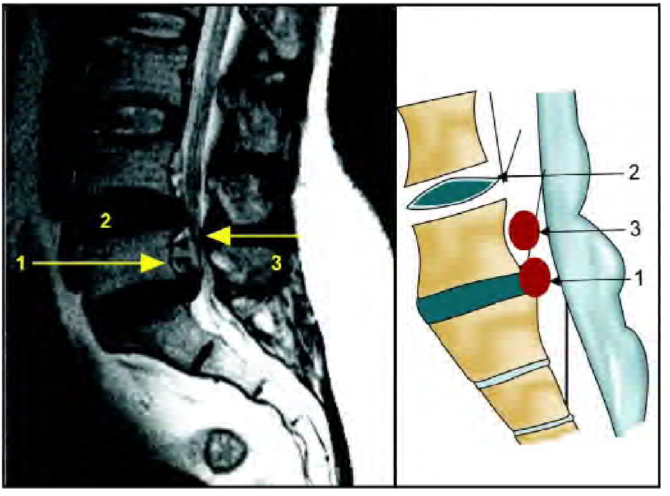


FIG. 5.33: T2W SAGITTAL

1. Sequestrated disc material, just behind the midvertebral body, lying free in the spinal canal
2. Degenerated disc
3. Posteriorly displaced thecal sac

1. Herniated disc
2. Normal disc
3. Sequestrated disc fragment

The diagram shows sequestrated disc in sagittal plane.

DISCUSSION

When an extruded nucleus breaks free of the parent disk, it is termed as *sequestered disc* or *free fragment*. A free disc fragment is an extruded disc herniation which is no longer in continuity with the parent disc material. The sequestered disc fragment may lie at the disc level, either anterior or posterior to the posterior longitudinal ligament, or can migrate inferior to, or less commonly, superior to the parent disc level. Free disc fragments may extend over two disc levels and be multiple in number. The lateral recesses or superiorly into the neural foramina are favorite locations for migration. In about half of the cases, the fragment consists predominantly of nuclear material, and the other half predominantly endplate material. Rarely, free disc fragments may extend into the thecal sac where they are properly referred to as "intradural disc herniations".

Free fragments also tend to resemble the parent disc on both CT scans and on T1W images. Most sequestered discs have higher signal than their disc of origin on T2-weighted images. The cause for this is unclear, but it may be due to increased water from granulation tissue, immune response, and inflammation.

If the disc fragment is near an interspace, sometimes it can be difficult to discern whether or not a pedicle of attachment remains. Free fragments can migrate some distance cephalad or rostral to the disk space, and it is important to alert the surgeon to their precise location.

Chronic disc herniations tend to be hypointense due to loss of water content.

Subligamentous disc fragments are contained by the posterior longitudinal ligament (PLL). Most contained disc fragments lateralize to either side of the anterior epidural space. An equal number migrate superiorly and inferiorly. The PLL has a high collagen content and is hypointense on MR. It can be seen as a thick dark line covering a contained herniated disc, usually seen best on sagittal images. The posterior margin of contained disc fragments usually maintain a smooth contour. Non-contained disc fragments have gone through the PLL. Either interruption or absence of the peripheral dark line suggests disruption of the PLL. Once through the PLL, the disc fragments are not bounded by any membranes, and they tend to have more irregular contours.

DISC HERNIATION-INTRAVERTEBRAL SCHMORL'S NODE

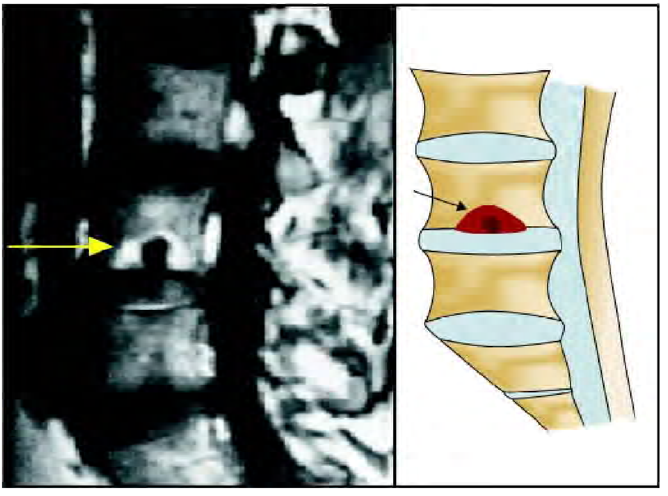


FIG. 5.34: T1W SAGITTAL

The T1W (note the dark CSF) sagittal view shows normal spinal cord and the covering. The degenerated disc between L4/L5 has herniated into the body L4 as shown by yellow arrow. The white surrounding is due to vertebral endplate changes

The blue arrow points to the Schmorl's node

Herniated discs in the cranio-caudal (vertical) direction through a break in one or both of the vertebral body endplates are referred to as “intravertebral herniations” (also known as Schmorl’s nodes). They are often surrounded by reactive bone marrow changes. Best seen in sagittal T1-weighted and T2-weighted scans. The intravertebral herniations in the example are located in the lower endplate of L4. The reactive bone marrow changes are hyperintense both on T1-and T2-weighted images (Modic type II changes). Nonacute Schmorl-node intrabody herniations are common spinal abnormalities regarded as incidental observations. They have been reported in 38–75% of the population. While intrabody herniations may occur secondary to endplate weakness related to bone dysplasia, neoplasms, infections, or any process that weakens the endplate or the underlying bone, most intrabody herniations probably form after axial loading trauma, with preferential extrusion of nuclear material through the vertebral endplate rather than an intact and normal annulus fibrosus. It has been suggested that asymptomatic intrabody herniations may be traceable to a specific occurrence of acute nonradiating low back pain in the patient’s history, which supports the concept that intrabody herniations (Schmorl nodes) occur through sites of endplate fracture. Type I vertebral body marrow changes have been described surrounding the acute intrabody herniations.

LIMBUS VERTEBRA

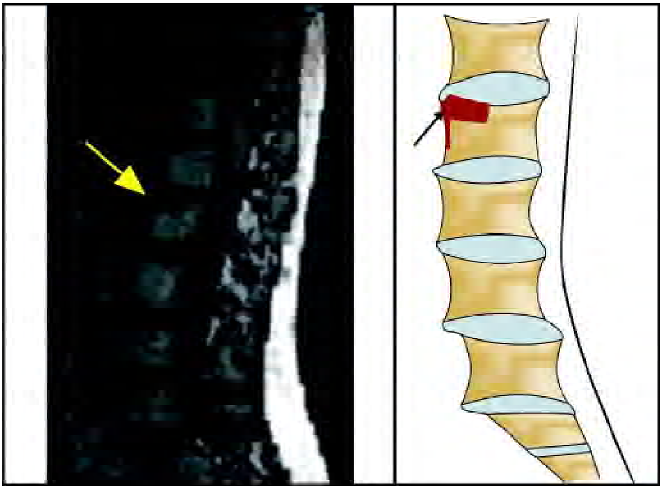


FIG. 5.35: T1W SAGITTAL

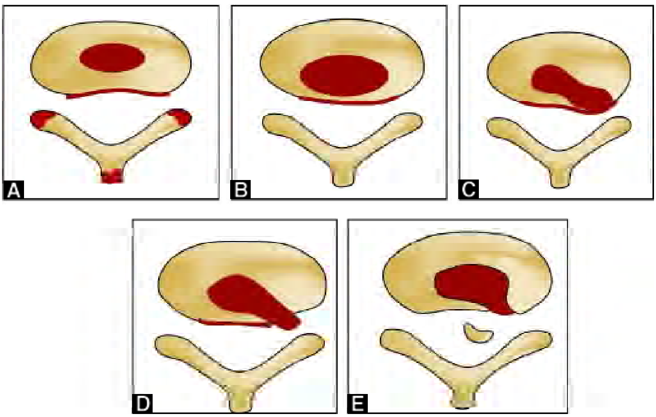
Yellow arrow points to a hypointense area (black) in the anterosuperior corner of the vertebral body

The blue arrow points a hypointense area in the anterosuperior corner of L2 vertebral body

In young individuals, intrabody (vertebral) herniation of disc material can instigate the formation of a "*limbus vertebra*". When herniation of the nucleus pulposus occurs through the ring apophysis prior to bony fusion, a small segment of the vertebral rim may become isolated. Limbus vertebrae are most commonly found in the midlumbar region, and less commonly in the mid-cervical region. They are characterized by a defect in the anterior margin of the

vertebral body usually at the anterior superior margin in the lumbar spine, and the anterior inferior margin in the cervical spine. Separation of a segment of rim of vertebral body ring apophysis. Note: Limbus vertebrae may result from fracture or from developmental abnormalities. Limbus vertebrae is commonly seen in patients who have had Scheuermann's disease. The lesions may be called "rim lesions".

SUMMARY OF DISC HERNIATION



FIGS 5.36A to E: DISC HERNIATION: (A) NORMAL; (B) BULGING DISC; (C) DISC PROTRUSION; (D) DISC EXTRUSION AND (E) DISC REQUESTRATION

a. Normally the intervertebral disc (*grey*) does not extend beyond the edges of the ring apophyses (*black line*). Note the concave black line.

b. In a symmetrically bulging disc, the disc tissue extends concentrically beyond the edges of the ring apophyses (50–100% of disc circumference). Note the convex black line.
c. Disc prolapse/herniation (into the spinal canal) may be a protrusion/extrusion/sequestration.
   - Protrusion—Herniated material more than 3 mm.
     - May be
       - central/paracentral/foraminal/extraforaminal
       - right/left side
     - This is the simplest and probably earliest type
   - Extrusion—Herniated material with a narrow neck, but incontact with parent disc.
   - Sequestration—Herniated material. Separate from parent disc, lying isolated in spinal canal.

- Different disc level may have different types of herniation, in the same patient.
- In young people disc may herniate into the vertebral body which may be central (Schmorl's nodes) or in the corners (Limbus vertebra).

VERTEBRAL ENDPLATE CHANGES

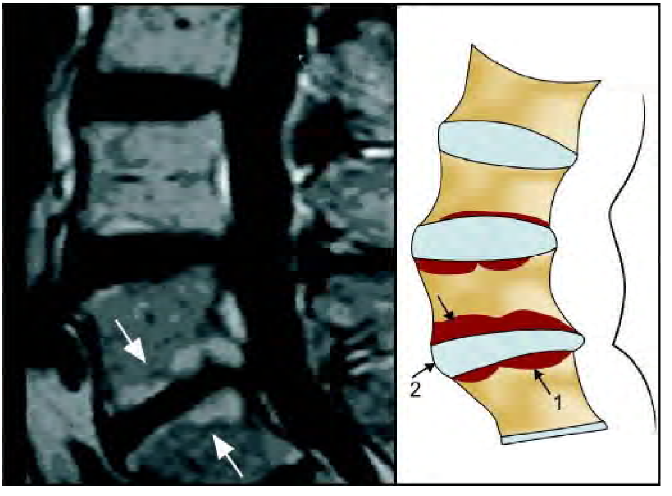


FIG. 5.37: T1W SAGITTAL

In this T1W sagittal image white arrows indicates vertebral endplate changes. In this patient, it is hyperintense (bright) signal corresponds to the fat content

1. Vertebral endplate hyper-intense signal due to fat content
2. Degenerated disc

Reactive changes involving the vertebral endplates and adjacent bone marrow are classified into 3 types: inflammatory (type 1), fatty (type 2) and osteosclerosis (type 3). The earliest radiographically visible changes of intervertebral disc degeneration are those that occur at the endplate. Three types of endplate changes have been described.

Type I: The first reaction of bone marrow edema and vascular congestion changes, earliest change, demonstrate

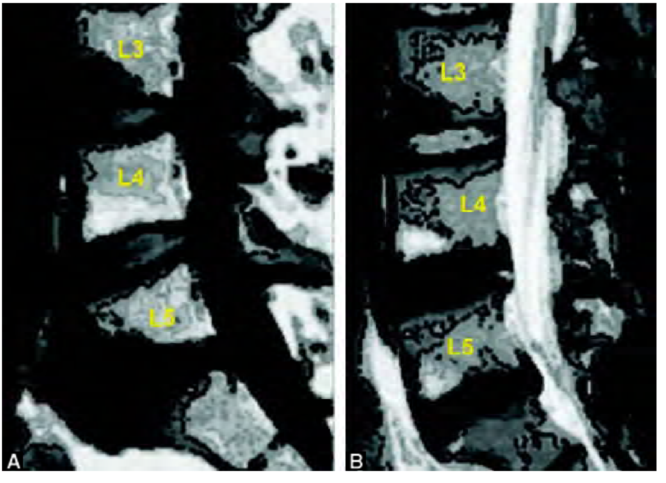
low signal intensity on T1-weighted images and high signal intensity on T2-weighted images. This stage is believed to reflect replacement of the endplate marrow with vascular fibrous, granulation tissue in response to chronic "injury". Type 1 change routinely enhances with gadolinium and can simulate osteomyelitis. With time, the bone marrow converts to a predominantly fatty marrow.

Type II changes, next change, show high signal intensity on T1-weighted and on T2-weighted images. This stage represents replacement of the endplate marrow with fatty tissue. Type II changes tend to remain stable with time. Longitudinal studies have shown this fatty marrow replacement to be stable over a 2–3 years period. Type 2 change is hyperintense on T1 and isointense to hypointense on T2-weighted images, the exact signal intensity dependent on the degree of T2-weighting.

Type III changes, or the final stage if it occurs, are represented by low signal intensity on both T1-weighted and T2-weighted images. Chronic disc disease leads to dense sclerosis of the vertebral endplates and adjacent vertebral bodies. This stage correlates with bony sclerosis seen on CT scans and plain films of severely degenerated endplates. This is the only endplate change visible on CT scans or radiographs. They are part of the normal aging process and must not be confused with other pathologic processes, such as tumor and infection conversion from Type 1 to Type 3 change generally requires a few years time.

Endplate MR signal changes as described by Modic

	T1	T2	Concomitant histological changes
Modic type 1	Hypointense	Hypointense	Granulation tissue within subchondral bone
Modic type 2	Hyperintense	Hyperintense or isotense	Fatty infiltration of adjacent bone marrow
Modic type 3	Hypointense	Hypointense	Endplate sclerosis



FIGS 5.38A and B: (A) T1W SAGITTAL; (B) T2W SAGITTAL

DISC LEVEL	MODIC TYPE	T1	T2
L5/S1	I	Decreased	Increased
L4/L5	II	Increased	Increased
L3/L4	III	Decreased	Decreased

Decreased	Hypointense	Black
Increased	Hyperintense	White

BURST FRACTURE

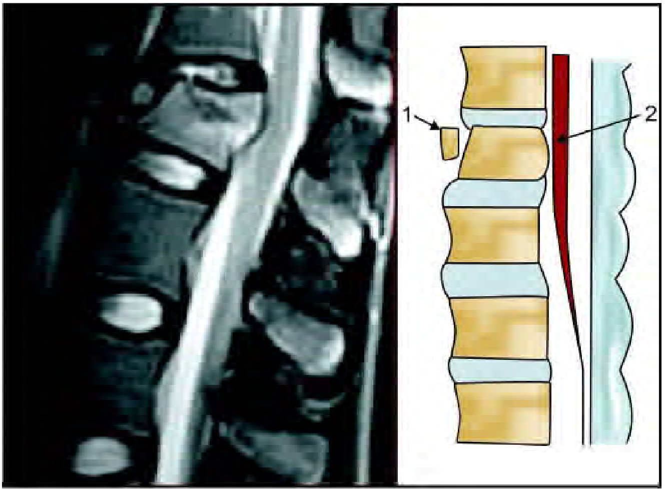


FIG. 5.39: T2W SAGITTAL

Decreased T12 vertebral body height with retropulsion of fracture fragments involving spinal canal, narrowing the thecal sac and deforming the ventral aspect of the spinal cord

1. Vertebral body fracture
2. Spinal cord compression

DISCUSSION

In patients with spinal trauma and neurological deficit, which cannot be explained by the findings on plain films, MRI gives valuable additional information about the soft tissues. In the majority of patients with neurological symptoms a cord contusion can be disclosed by MRI but more importantly it rules out a traumatic disc herniation or epidural hematoma which requires surgery. The degree of cord contusion might also be helpful for establishing prognosis. Significant traumatic disc herniation and epidural hematomas as the main causes of neurological symptoms are rare but extremely important to rule out since they can be treated. MRI is also valuable in the post-traumatic stage, specially for evaluation of possible cyst formation in patients with increasing neurological symptoms.

Burst fractures are classically due to vertical compression associated with axial loading with or without a component of flexion. They involve the anterior and middle spinal columns, but spare the posterior column (pedicles, facets, spinous processes and all associated ligaments). The anterior aspect of the vertebral body is relatively protected by stabilizing ligaments and musculature; however, the posterior aspect of the vertebral body — the middle column — is open to the spinal canal. With a sufficient axial load, the adjacent disc herniates into the vertebral body and preferentially disseminates the force laterally and posteriorly. All burst fractures have the potential to be neurologically devastating and are considered unstable. MR Imaging features include the following:

- Diminished vertebral body height
- increased marrow T2 signal of the involved vertebral body
- Old vs new fracture—in old fractures signal intensity same in T1W and T2W, In new fractures signal intensity is increased in T2W and decreased in T1W
- Useful for the evaluation of associated epidural and soft tissue hemorrhage
- Essential for evaluation of the spinal cord in patients with neurologic symptoms.

Spinal *stability* indicates that the bony and ligamentous elements of the spinal column will remain in the same relative positions without shifting or separating from each other over time. Spinal *instability* indicates that, without stabilization, the spinal elements may shift and, by shifting, induce additional neurologic, soft tissue, or osseous injury. The *three-column model* is often used to assess and characterize stability of the spinal column. In this model, the spinal column is considered to have three stability elements or "columns". The anterior column consists of the anterior longitudinal ligament plus the anterior two thirds of the vertebral bodies, discs, and annuli. The middle column consists of the posterior third of the vertebral bodies and discs, the posterior longitudinal ligament, and the posterior portion of the annuli. The posterior column includes all of the osseous and ligamentous structures posterior to the posterior longitudinal ligament. Unstable injuries as either an injury involving all three columns or an injury that involves two contiguous columns, that is, the anterior and middle columns or the middle and posterior column.

SPINAL TUBERCULOSIS—COLD ABSCESS (Example 1)

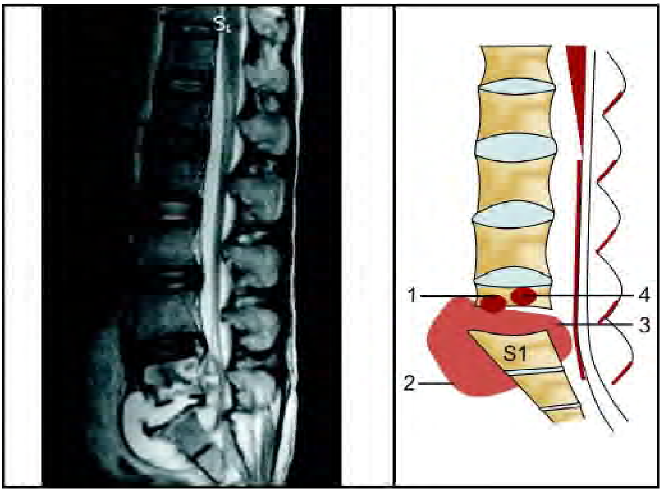


FIG. 5.40: T2W SAGITTAL

Destruction of L5 body and L5/S1 disc. The cold abscess extends to presacral region, paravertebral region and intraspinal region. Note the mass effect on the cauda equina

1. L5 vertebral body
2. Presacral extension of abscess
3. Intraspinal extension-extradural space
4. Involvement of L5 body

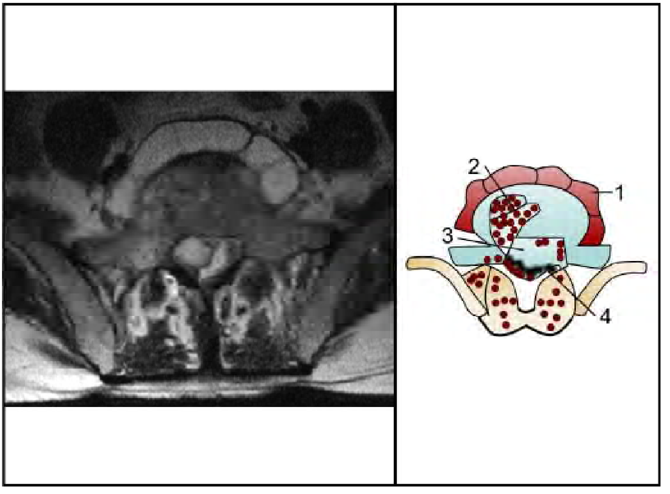


FIG. 5.41: T2W AXIAL

This axial image shows marked pre-vertebral collection, with extension to intraspinal and extradural spaces. The thecal sac is compressed and displaced. The vertebral body shows signal changes indicating involvement

1. Prevertebral collection
2. Vertebral body edema
3. Intraspinal extension
4. Displaced thecal sac

Discussion

Twenty percent of patients with TB have multiple lesions. Spinal tuberculosis is always a secondary disease from another primary site. Spinal TB is an indolent granulomatous infection, most often seen in the lower thoracic region, but can be seen at any spinal level. Very often we see typical caries spine involving lumbo-sacral region. The intervertebral disc may be involved (discitis), as well as

most of the vertebral body and posterior elements (osteo-myelitits). As the vertebrae degenerate and collapse along the anterior spine, the gibbus or kyphotic deformity results, characteristic of Pott's disease. Most commonly, spinal TB involves the disc with 2 adjacent vertebral bodies and opposing endplates. There is destruction of the disc space, and/or development of an epidural or large paravertebral (psoas) abscess.

MRI typically demonstrates signal alteration in the early form like the other spondylitides. The findings of destruction at the vertebral end plates of involving two consecutive vertebrae with involvement of the intervening disc and loss of cortical definition, vertebral collapse, marked epidural encroachment, epidural infection, and vertebral intraosseous abscess with ring enhancement are more common and marked then with pyogenic spondylitis. Fragmentation, involvement of the posterior elements, involvement of more than two vertebral bodies, skip areas, subligamentous spread of infection, anterior vertebral osteolysis/wedging and gibbus deformity, and intersegmental fusions are other typical findings of tuberculous spondylitis. Large paraspinal masses and paraspinal soft tissue involvement/abscess are generally seen with well-defined borders, whereas ill-defined signal alterations and contrast enhancement are frequent in the evaluation of pyogenic spondylitis. Fistula formation of tuberculous spondylitis is another differentiating finding from pyogenic spondylitis. The cord displacement or compression due to epidural involvement can be detected with axial and sagittal imaging.

There are low signals on T1W images and high signals on T2W images within the areas of osseous and soft tissue changes. The enhancement pattern is usually heterogeneous, whereas it is homogeneous in pyogenic spondylitis. A central nonenhancing but peripheral enhancing rim may also be seen. Involved ligaments, an epidural mass, and inflamed meninges may also be demonstrated with contrast enhancement.

Follow-up MRI examinations are useful for monitoring therapy. The earliest sign of healing is a reduction in the amount of inflamed soft tissue. A progressive increase in signal intensity on T1W imaging has been found to correlate well with resolving symptoms. Although a reduction in and eventual loss of contrast enhancement are useful signs of recovery, persistent or increasing enhancement is not necessarily an indication of either deterioration or treatment failure.

SPINAL TUBERCULOSIS

Key Findings

- Destruction at vertebral endplates involving two consecutive vertebrae with intervening disc and loss of cortical definition, vertebral collapse
- Marked epidural encroachment, epidural infection, and vertebral intraosseous abscess with ring enhancement
- Fragmentation, involvement of posterior elements, involvement of more than two vertebral bodies, skip areas, subligamentous spread of infection, anterior

vertebral osteolysis/wedging and gibbus deformity, intersegmental fusions

- Large paraspinal masses and paraspinal soft tissue involvement/abscess are generally seen with well-defined borders
- Fistula formation, cord displacement or compression due to epidural involvement
- Low signals on T1-weighted images and high signals on T2-weighted and short tau inversion recovery (STIR) images within areas of osseous and soft tissue changes
- Enhancement pattern is usually heterogeneous; central nonenhancing with peripheral enhancing rim may also be seen
- Involved ligaments, epidural mass, inflamed meninges may also be demonstrated with contrast enhancement
- Progressive increase in signal intensity on T1-weighted imaging has been found to correlate well with resolving symptoms.

SPINAL TUBERCULOSIS (Example 2)

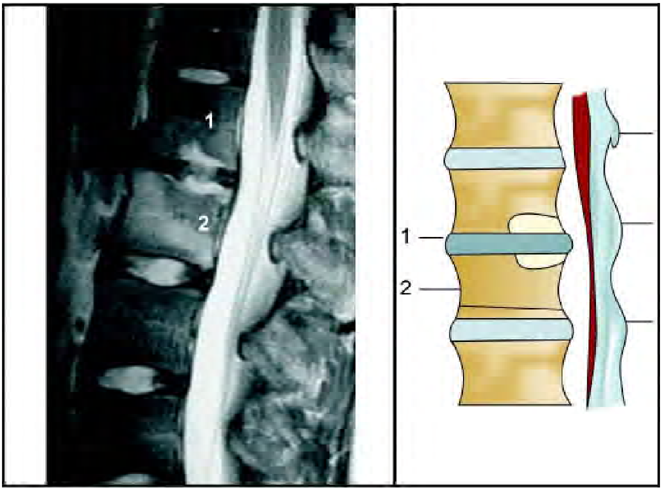


FIG. 5.42: EARLY SIGNS OF SPINAL TB

Sagittal, T2-weighted MR image shows increased signal intensity of the vertebral bodies immediately adjacent to the L1–2 intervertebral space

A more diffuse signal intensity increase throughout the L2 vertebral body also is seen. Note that the disc itself has relatively low signal intensity except immediately at the site of the endplate signal intensity alteration. Corresponding sagittal, (not shown) contrast material-enhanced, T1-weighted MR image showed enhancement of the abnormal endplates. Slight enhancement of the parent disc is also seen

PYOGENIC SPONDYLITIS

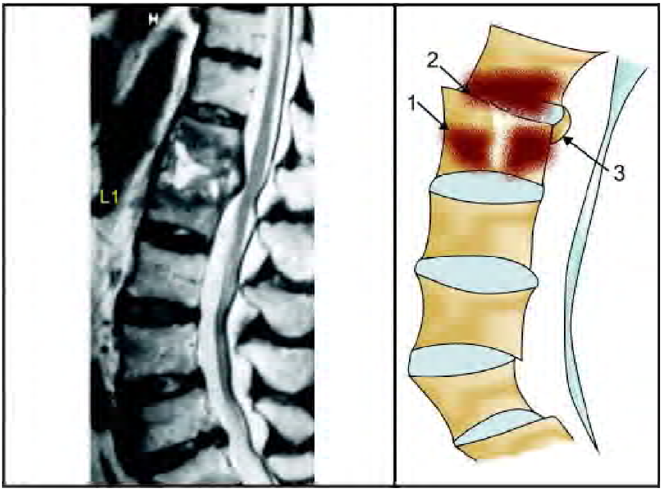


FIG. 5.43: T2W SAGITTAL

Destruction of T12/L1 and adjacent vertebral bodies. The bone marrow signal is altered with focal increasd signal due to necrosis

1. Collapse of vertebral body
2. Altered signal due to edema
3. Stretched posterior ligament

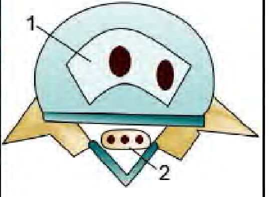


FIG. 5.44: T2W AXIAL

The vertebral body shows central area of high signal intensity indicating marked necrosis. The spinal cord is spared

1. Central area of necrosis
2. Normal spinal cord and coverings

DISCUSSION

MRI is as sensitive, specific, and accurate (96%, 94%, and 92%, respectively) as combined nuclear medicine studies and is the imaging modality of choice for the diagnosis of spondylitis. The earliest response of the vertebral body to infection is increase in extracellular water content in production of exudate containing white blood cells and fibrin within vertebral marrow (a manifestation of inflammatory reaction and associated ischemic changes) and reactive bone marrow stimulation, which are responsible for the abnormal

signal for infection on both T1-weighted (T1W) and T2-weighted (T2W) images. Morphologic alteration as loss of definition of the endplate of a single vertebra becomes more marked in time. An infective process may progress underneath the ligaments or across the disc with signal alteration on precontrast T1W and T2W images and with contrast enhancement on postcontrast T1W images, if the infection is not treated. Increased disc signal on T2W images is accompanied by obliteration of intranuclear cleft and reduction of the disc height. The next stage is the classic appearance of a loss of cortical continuity of the adjacent endplates and progressed destruction of the vertebral bodies together with disc destruction and soft tissue infiltration. This can extend posteriorly into the epidural space and/or laterally into the paraspinal area. These extensions can be much better defined at the postcontrast images. The epidural venous plexus should not be confused with epidural involvement. However, engorgement of epidural basivertebral veins from direct extension of the inflammatory process, mechanical obstruction to venous drainage, or both, may occur. Contrast is mandatory and increases conspicuity, specificity, and observer confidence in the diagnosis and facilitates the treatment planning and also treatment monitoring of the spinal infections. Contrast enhancement is one of the other earliest signs, together with the signal change, and is pathognomonic in the acute inflammatory episode and even in the subtle infection; it then persists to a varying degree for several weeks or months. Fat-suppressed T1W imaging can be helpful to obtain better

contrast between the tissues for postcontrast evaluation. The measurement of percentage enhancement has been shown to be a reliable method to quantify diffuse bone marrow changes. It is also helpful to differentiate the disc, the body, and the edema and the phlegmon or abscess. This differentiation is important for treatment planning, with surgery being indicated for an abscess whereas a conservative approach is preferred for phlegmon. When contrast enhancement no longer occurs, active inflammation can be excluded.

MRI findings of pyogenic spondylitis and discitis include the following:

1. Decreased signal intensity on T1W images and increased signal intensity on T2W images, with contrast enhancement
2. Irregularity, erosion, and destruction of endplates of vertebral bodies with interruption of the normal signal void of the cortical endplate
3. Invariably reduced disc height, loss of intranuclear cleft on T2W imaging, disc protrusion, and nonanatomic contrast enhancement
4. Paravertebral soft tissue infiltration/abscess (hyperintense on T2W imaging, hypointense on T1W imaging, and homogeneous or ring-like enhancement)
5. Epidural extension with contrast enhancement (phlegmon: homogeneous; abscess: ring-like)
6. Late/healing stage of the infective process: reactive bone changes, new bone formations, osteophytosis, sclerosis, vertebral body height changes, kyphosis, scoliosis,

spondylolisthesis, ankylosis, bony bridges across the annulus.

The destructive vertebral bone lesion associated with a well-preserved disc space with sharp endplates favors a diagnosis of neoplastic infiltration, whereas the destructive bone lesion associated with a poorly defined vertebral bony endplate with or without loss of disc height suggests infection with a better prognosis.

VERTEBRAL TUMOR—HEMANGIOMA

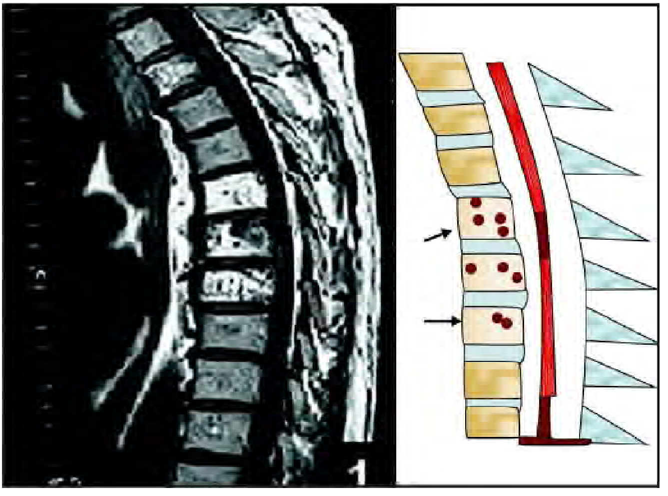


FIG. 5.45: T1W SAGITTAL

The bodies of many vertebrae show abnormal white colored signals, unlike the normal gray color from bone marrow. These hyperintense signals are diagnostic of vertebral hemangiomas. The most common cause of such hyperintense foci in T1W images is hemangiomas. Other causes include fat methemoglobin, mucin, high protein content, gadolinum contrast agent, etc.

The blue arrows point to hyperintense foci classically seen in hemangiomas

DISCUSSION

Hemangiomas are the most common benign vertebral tumor, typically occurring in the lower thoracic and upper lumbar regions. Most hemangiomas are discovered incidentally. When visualized, a hemangioma characteristically presents as a well-demarcated hyperintense lesion with coarse vertical trabeculae, appearing longitudinally and transversely in a "corduroy" and "polka dot" pattern, respectively. MR findings depend upon the proportion of fat and vascularity of the tumor. Fat content corresponds with T1 hyperintensity, whereas vascularity correlates with high T2 signal and contrast enhancement. Aggressive hemangiomas present iso/hypointense to bone on T1WIs and hyperintense on T2WI, making differentiation from metastasis difficult. The differential diagnosis for vertebral hemangioma also includes focal fatty marrow, Paget disease, severe disc degeneration, and post-radiation changes.

VERTEBRAL TUMOR—LYMPHOMA

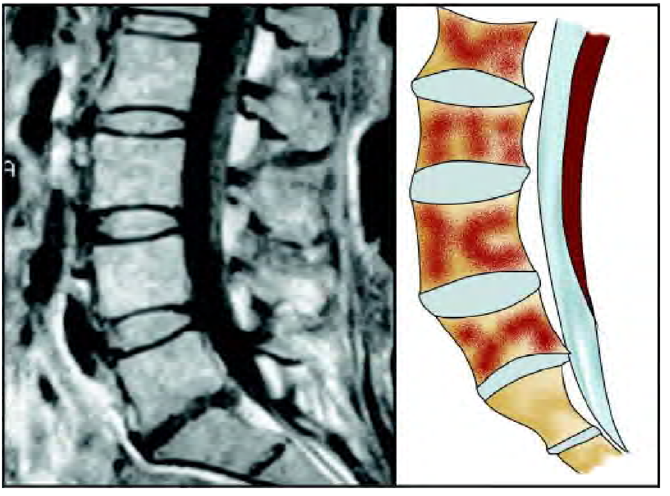


FIG. 5.46: T1W SAGITTAL VIEW

The vertebral bodies show diffuse increase signal intensity giving it a mosaic pattern

The altered bone marrow intensity is suggestive of bone marrow infiltrates

DISCUSSION

Note the mottled appearance of the marrow. Diffuse osteopenia, multiple myeloma, and systemic marrow replacement diseases will give such abnormal marrow appearance. MR imaging utilizing T1, proton density, and T2 sequences, as well as fat suppression and gadolinium enhancement techniques, are useful diagnostic features of MRI when evaluating bone marrow diseases.

A lymphoma is a lymphoreticular neoplasm that may occur in a variety of specific disease locations and cellular differentiations (epidural, osseous, leptomeningitic, intramedullary).

On T1W imaging the epidural lesion is isointense, homogeneous and the osseous lesion is hypointense to normal marrow. With T2W imaging the epidural lesion is isointense/hyperintense to cord and the osseous lesion is variably isointense/hyperintense. After administration of a contrast agent T1W imaging shows the epidural lesion to enhance intensely and uniformly and diffuse uniform enhancement of an osseous lesion. Dynamic contrast enhanced MRI shows bone marrow enhancement in a patient with lymphoproliferative disease with an accuracy of 99%.

VERTEBRAL SECONDARIES—AN OVERVIEW

- In the initial stage with no disc space involvement, it is very difficult to differentiate the infection from neoplastic involvement.
- A well-preserved disc space with sharp endplates favors a diagnosis of neoplastic infiltration (in rare instances, metastatic involvement of the disc can also be seen).
- Consecutive vertebral involvement is more frequent in spondylitis than in tumoral infiltration.
- The intact vertebral endplate favors the diagnosis of tumor.
- Both infections and tumors may show skip lesions.

Soft tissue involvement is a diffuse pattern in infections but usually well-defined in tumors.

- Signal characteristics are not reliable signs for distinguishing tumors from infection because both of them demonstrated low signal intensity on T1W imaging and high signal intensity on T2W imaging.

On T1W imaging the signal intensity is different from normal marrow. Hypointense solitary or multiple lesions may be seen. The intervertebral discs are generally spared. On T2W imaging sclerotic metastases appear hypointense. After contrast agent administration T1W imaging shows variable enhancement depending on the degree of sclerosis.

Approximately 5% of cancer patients have intradural extramedullary spinal metastasis. They are either drop lesions from intracranial metastasis of breast (36%), lymphoma (28%), or lung (16%) cancer and melanoma or drop lesions from intracranial primary CNS tumors.

Leptomeningeal (intradural extramedullary space) metastases demonstrate three patterns on imaging:

1. Diffuse contrast enhancement along the pia mater of the cord and the nerve roots, hence the name “sugar coating” pattern
2. Multiple contrast-enhancing nodules in the subarachnoid space
3. A contrast-enhancing single mass in the subarachnoid space.

Metastases present as isointensity on T1W images, hyperintensity on T2W, and strong linear, nodular or mass-like contrast enhancement, according to the dissemination pattern.

Metastatic lesions of the spine are divided into blastic and lytic osseous metastases. In blastic osseous metastases, bone production exceeds bone destruction, whereas in lytic metastases, bone destruction is more prevalent. Mixed lesion patterns may occur as well.

Overall, most metastatic lesions of the spine originate from breast, lung, or prostate cancer. Osteoblastic primaries include prostate cancer, bladder cancer, nasopharyngeal cancers, carcinoid, and medulloblastoma. Mixed patterns may occur in lung, breast, ovarian, and cervical cancers. Common primaries for lytic metastases are breast, lung, renal bladder, thyroid, oropharyngeal, and nasopharyngeal cancers; cancers of the gastrointestinal tract; and ovarian and cervical cancers.

MRI is extremely sensitive for the detection of spinal metastases. T1-weighted sequences distinguish between the

high fat content of unaffected bone marrow and the metastatic lesion. The metastatic lesions alter the usual fat content within the vertebral bodies, thereby causing a decrease in signal intensity on T1-weighted images. T2-weighted sequences are also helpful, because abnormal bone marrow usually demonstrates increased signal intensity on T2-weighted images. Malignant fractures due to metastases tend to have convex outward anterior and posterior margins, compared with the more sharply angulated borders of acute benign osteoporotic fractures. In addition, signal changes in the affected vertebra are usually more homogeneous in malignant fractures, with an absent fatty marrow signal intensity.

SPINAL TUMOR—VERTEBRAL SECONDARIES FROM LUNG

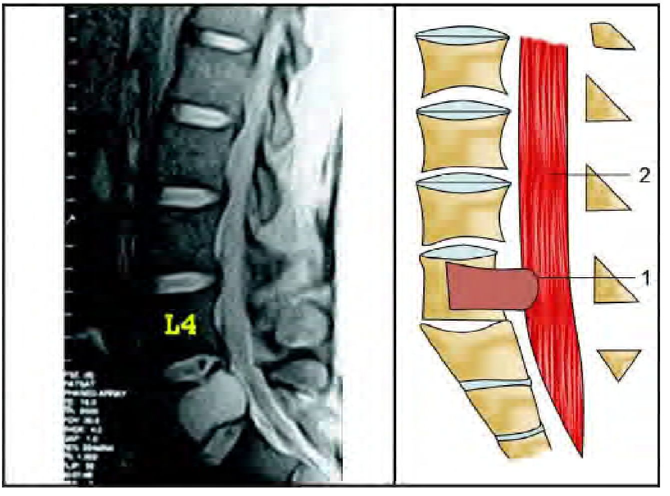
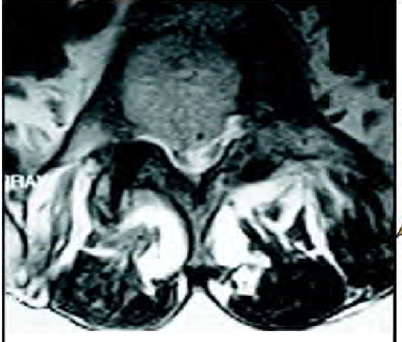


FIG. 5.47: T2W SAGITTAL

This image shows a well-defined hyperintense mass involving the L5 body, sparing the disc. This is a biopsy proved secondary from carcinoma lung

1. Very bright (hyperintense) vertebral secondary
2. Spinal nerve roots

SPINAL TUMOR—VERTEBRAL SECONDARIES



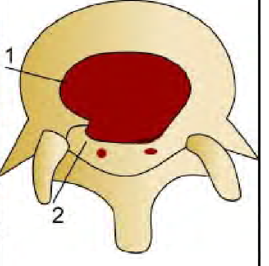


FIG. 5.48: T2W AXIAL

This image shows the mass from vertebral body encroaching the spinal canal, compressing the nerve root. This is a secondary from lung carcinoma .

1. Mass from vertebral body
2. Spinal canal encrochment

VERTEBRAL SECONDARIES—IVORY SECONDARY

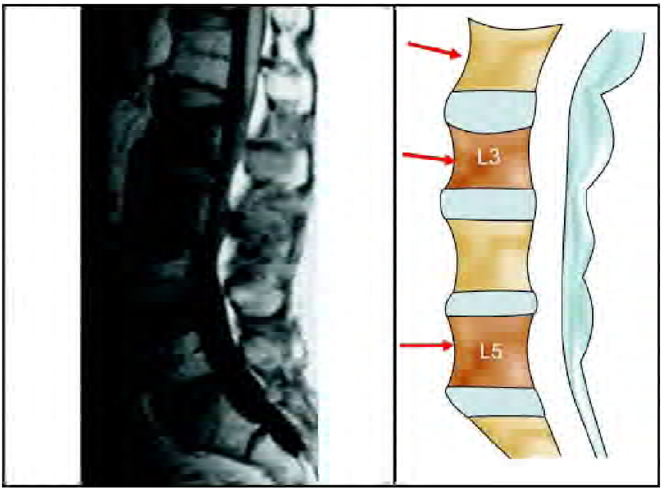


FIG. 5.49: T1W SAGITTAL

Increased signal (brightness) in the vertebral bodies

Blue Arrow—Diffuse increased signal in bodies of L3 and L5
Red arrow normal signal from vertebral body

IVORY VERTEBRA

Vertebral bodies show increased brightness (hyporintense signal) in MRI. This is unlike X-ray (conventional X-ray and CT scan) wherin they appear ivory white. The differential diagnosis of such findings include, apart from metastasis, Paget’s disease, fibrous dysplasia, lymphoma, osteogenic sarcoma, infection, hemangiomas, etc.

While tumor spread is thought to be exclusively by way of blood circulation, it is not clear why the spine is affected disproportionately more compared to other organs, especially considering its relatively small proportion of cardiac output. Metastatic growth within the vertebral body often undermines the endplates contributing to vertebral collapse. While there is a general belief that cord compression occurs primarily from the anterior direction, infiltrated lateral and posterior spinal elements almost as often cause compression from their respective directions. Epidural cord compression from a metastatic tumor is most often due to an epidural soft tissue mass expanding from the vertebral metastasis and rarely from an epidural bony mass.

MR is considered to be the most sensitive modality for the analysis of spine metastasis because it provides images of the bone marrow, where the metastatic disease primarily exists. Spinal metastasis is hypointense compared to normal vertebral marrow on T1-weighted images. If used alone, however, sagittal T1-weighted images detect only 87% of vertebral metastases present. To increase sensitivity, additional scans are necessary. T1-weighted post-contrast imaging, T2-weighted FSE (fast spin echo), STIR (short tau inversion recovery), IR-FSE (Inversion Recovery Fast Spin Echo) can all yield additional information and require/utilize fat saturation (FS) to reduce background signal. IR-FSE scans are comparable to T2-weighted FS-FSE in length of scan and quality.

VERTEBRAL SECONDARIES—PROSTATE SECONDARY

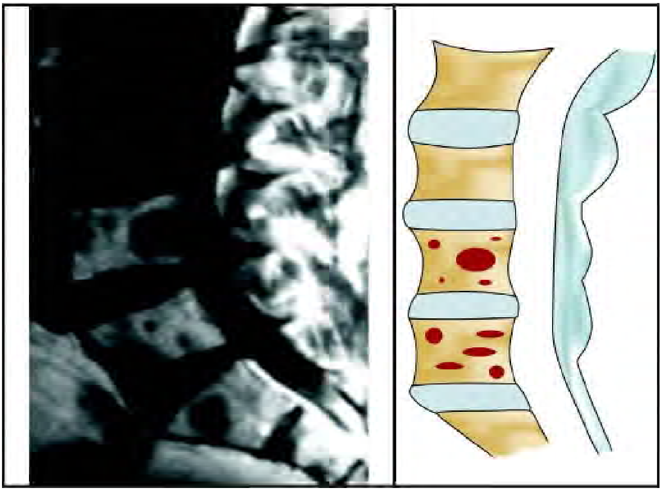


FIG. 5.50: T1W SAGITTAL

Prostate Secondaries: Multiple vertebral bodies show, discrete hyperintense foci. Note the disc sparing

SPINAL CORD TRAUMA

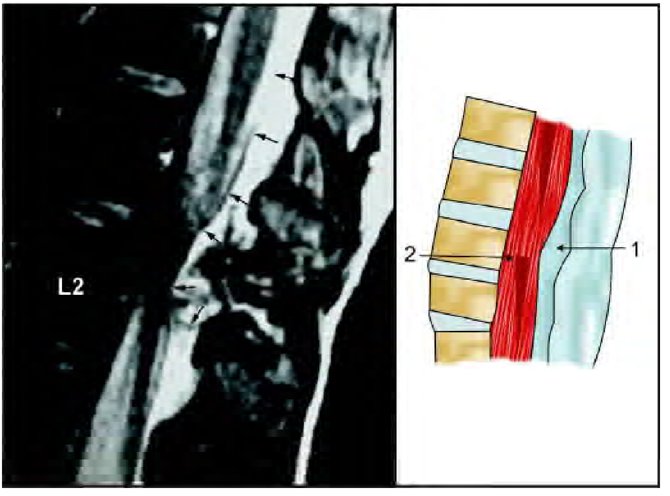


FIG. 5.51: T2W SAGITTAL

A large dorsal epidural hematoma displacing the posterior duramater. (black arrows). The roots of cauda equina are compressed

1. Epidural hematoma
2. Cauda equina compression

A spinal epidural hematoma is an accumulation of blood in the epidural space that can mechanically compress the spinal cord. Spinal epidural hematoma (usually thoracic or lumbar) is rare but may result from back trauma, anticoagulant or thrombolytic therapy, or, in patients with bleeding diatheses, lumbar puncture. Hematoma is suspected in patients with acute, nontraumatic spinal cord compression or sudden, unexplained lower extremity paresis, particularly

if a possible cause (e.g. trauma, bleeding diathesis) is present. Sagittal MR imaging typically shows hematoma in the posterior epidural space with well-defined borders tapering superiorly and inferiorly. The dura matter separates the hematoma from the spinal cord on T1 and T2-weighted images In acute stage (within 24 hours of onset), the epidural hematoma is usually isointense on T1-weighted image. On T2-weighted image, there may be homogeneous high-signal or inhomogeneous areas of mixed high and low-signal. After 24 hours, there is usually a high-signal on T1-weighted images; T2-weighted images.

The MR signal of blood has characteristic signal pattern, irrespective or its cause or site. The varying signal patterns are generated by various blood degradation products like deoxy hemoglobin, methemoglobin and hemosiderin, etc. The following table shows the MR signal pattern

Characteristic of acute, sub acute, and chronic blood collections.

Spinal epidural hematoma needs to be differentiated from epidural metastases, epidural abscess and extruded or migrated disc fragment. A careful history and MR imaging findings may help to narrow the differential diagnosis. Prompt surgical evacuation is the treatment of choice in spinal epidural hematomas of primary importance in spine trauma is the status of the cord. Cord injuries can have a variable appearance. Severe injuries may reveal disruption of cord structure or even complete transection. Milder contusions show high-signal edema within the cord on T2-weighted images, and perhaps cord swelling.

Evolution of Parenchymal Hematomas as seen at MR imaging

				Intensity compared to brain	
Stage	**Age**	**Compartment**	**Hemoglobin**	**T1 weighted image**	**T2-weighted image**
Hyperacute	< 24 h	Intracellular	Oxyhemoglobin	Isointense	Slightly hyperintense
Acute	1–3 d	Intracellular	Deoxyhemoglobin	Slightly hypointense	Very hypointense
Subacute					
Early	> 3 d	Intracellular	Methemoglobin	Very hyperintense	Very hypointense
Late	> 7 d	Extracellular	Methemoglobin	Very hyperintense	Very hyperintense
Chronic	> 14 d	Extracellular	Hemichromes	Isointense	Slightly hyperintense
Center					
Rim		Intracellular	Hemosiderin	Slightly hypointense	Very hypointense

The presence of cord hemorrhage is associated with a poorer prognosis. In the setting of new or progressive signs of neurologic dysfunction, MR can facilitate the diagnosis of delayed complications, such as disc herniation, arachnoid cyst, and post-traumatic cord syrinx. The syrinx or intramedullary cyst first forms at the site of injury but can extend some distance beyond and become quite large. MR readily distinguishes between syrinx and other post-traumatic changes. Myelomalacia and gliosis are focal processes with poorly defined margins and are associated with cord atrophy. A syrinx has well-defined margins and frequently expands the cord.

SPINAL CORD INFLAMMATIONS
TRANSVERSE MYELITIS

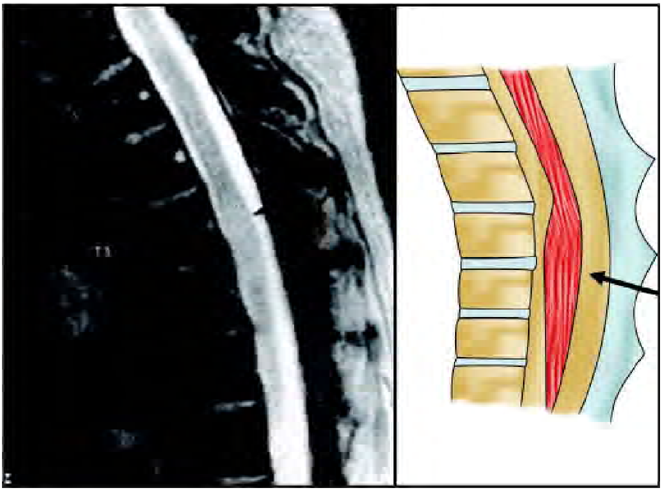


FIG. 5.52: T2W SAGITTAL

Focal cord enlargement in a case of acute Paraplegia

The blue arrow shows cord enlargement

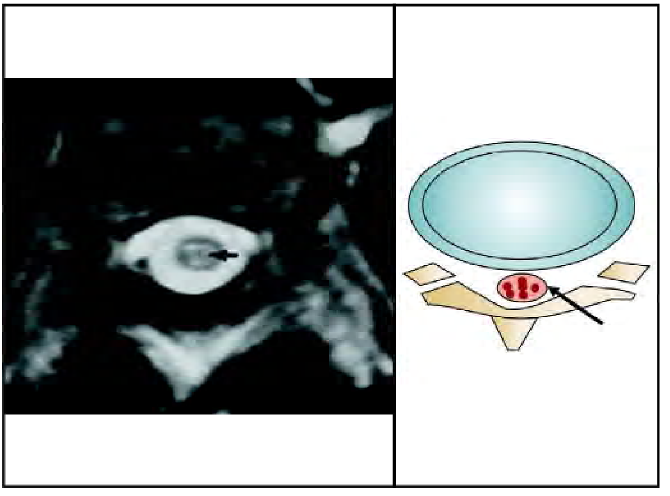


FIG. 5.53: T2W AXIAL

The black arrow points to the central Hyperintense foci

The blue arrow points to the focal enlargement and increased signal intensity

Transverse myelitis (TM) is a neurological disorder caused by an inflammatory process of the grey and white matter of the spinal cord, and can cause axonal demyelination. This demyelination arises idiopathically following infections or vaccination, or due to multiple sclerosis. The lesions are inflammatory, and involve the spinal cord on both sides. With acute transverse myelitis, the onset is sudden and progresses rapidly in hours and days. The main conditions to be considered in the differential diagnosis are: acute spinal cord trauma, acute compressive lesions

of the spinal cord such as epidural metastatic tumor, and infarction of the spinal cord, usually due to insufficiency of the anterior spinal artery.

MR imaging findings in patients with TM have described local enlargement of the spinal cord and increased signal intensity. Scans done early in the course of the disease may not show any signal intensity on T2 weighted images, but high signal intensity extending over several spinal segments. Commonly, three to four segments involvement are diagnostic. The centrally located high signal intensity occupied more than two thirds of the cross-sectional area of the cord. In multiple sclerosis, plaques are usually located peripherally and occupy less than half the cross-sectional area of the cord. There is peripheral contrast enhancement of high intensity signal. In multiple sclerosis the spinal cord involvement is less than 2/3rd in axial section, vertical extent is also less than 2 segment and there is central homogeneous enhancement.

The MR changes in ATM depend on the underlying pathology which includes edema, demyelination, necrosis hemorrhage and myelomalacia. The changes not only vary with the severity and rapidity of disease progression but are also dependent on timing of MRI study, strength of magnetic coil and extent of MRI examination, i.e. if only a clinically relevant area or whole of spinal cord is imaged.

The progression of these findings to spinal cord atrophy has also been described. This has also been associated with poor recovery of the patients.

SPINAL CORD INFLAMMATION

ARACHNOIDITIS

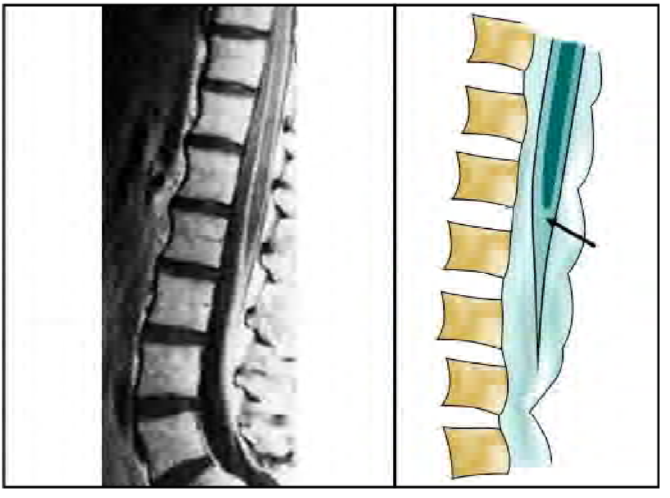


FIG. 5.54: T1W SAGITTAL IMAGE WITH CONTRAST INJECTION

Spinal meningitis (Arachnoiditis)

Post contrast T1W sagittal image shows enhancement of the meninges, especially the dura and arachnoid mater

The blue arrow point to the enhancing meningeal coverings

Arachnoiditis is a broad term denoting inflammation of the meninges and subarachnoid space. Infectious etiologies include bacterial, viral, fungal, and parasitic agents. Noninfectious inflammatory processes include surgery, intrathecal hemorrhage, and the administration of

intrathecal agents such as myelographic contrast media, anesthetics, and steroids. Neoplasia includes the hematogenous spread of systemic tumors, such as breast and lung carcinoma, melanoma, and non-Hodgkin lymphoma. Neoplasia also includes direct seeding of the cerebrospinal fluid (CSF) from primary central nervous system (CNS) tumors such as glioblastoma multiforme, medulloblastoma, ependymoma, and choroid plexus carcinoma.

MRI is the study of choice for the diagnostic evaluation of arachnoiditis. T1-weighted MRIs may reveal an indistinct or absent cord outline due to the increase in the signal intensity of the surrounding CSF This may be the result of an elevation in CSF protein content, the presence of inflammatory exudate, or the formation of adhesions along the surface of the spinal cord.

T2-weighted MRIs may demonstrate CSF loculation and obliteration of the subarachnoid space or irregularly thickened, clumped nerve roots, which occasionally may be misinterpreted as a tethered cord or a thickened filum terminale with more severe arachnoiditis, progression of nerve root clumping and leptomeningeal adhesions may lead to angular defects in the dural sac. Peripheral adherence of the nerve roots to the walls of the thecal sac produces the so-called featureless, or empty, sac.

Contrast enhancement is an inconstant finding. When it does occur, enhancement may be the result of a vascular network within the fibrous stroma that develops in the subarachnoid space. Three patterns of enhancement have been described:

- The most common pattern of enhancement is a smooth, linear layer of enhancement outlining the surface of the cord and nerve roots.
- The second most common pattern is a nodular pattern with discrete foci of enhancement seen along the surface of the cord and nerve roots.
- The least-common pattern consists of diffuse intradural enhancement that completely fills the subarachnoid space.

Syringomyelia is a complication of arachnoiditis.

SPINAL TUMORS—AN OVERVIEW

Spinal tumors comprise a large spectrum of distinct histologic entities that may arise primarily from the spinal cord (intra-axial or intramedullary space), the surrounding lepto-meninges (intradural/extramedullary space), or the extradural soft tissues and bony structures (extradural space). All three anatomic compartments may also be secondarily affected by metastatic disease from a known or unknown distant primary neoplasm.

MRI is the diagnostic modality of choice for the assessment of spinal neoplasia. Its superior soft tissue visualization and contrast differentiation between normal and pathologic tissues allows early diagnosis, assessment of associated edema, differentiation between solid and cystic components, and accurate anatomic localization of the neoplasm, thus facilitating characterization even of specific histologic subtypes. Ependymomas, astrocytomas, and gangliogliomas are the most common intramedullary tumors,

followed by hemangioblastomas and metastases. The histologic spectrum of intradural extramedullary tumors is dominated by schwannomas and meningiomas. In the extradural space, metastatic disease involving the osseous spinal elements is the most common neoplastic cause of spinal myelopathy, with primary bone tumors such as osteoblastomas, giant cell tumors, or aneurysmal bone cysts being less common.

Focal spinal cord expansion with tapered narrowing of the adjacent subarachnoidal space but intact dura mater point to the location of a (intramedullary) space-occupying mass within the spinal cord. Intramedullary signal alterations in the absence of spinal cord expansion favor a non-neoplastic cause, such as motor neuron degenerative diseases (e.g. amyotrophic lateral sclerosis), inflammatory diseases (e.g. poliomyelitis, chronic demyelination associated with multiple sclerosis), vascular causes (e.g. nonhemorrhagic cord infarction, amyloid angiopathy), or gliosis (e.g. chronic compressive myelopathy). Most of these are gliomas. Ependymomas and astrocytomas occur with about equal frequency in the spinal cord, but ependymomas greatly predominate in the filum terminale, especially in children where they are usually of the myxopapillary type. The differentiation between neoplastic and non-neoplastic diseases of the spine is crucial for planning therapy.

Neurinomas and meningiomas are by far the commonest lesions in the intradural extramedullary location, significant extradural components are present in about 7% of meningiomas and 30% of neurinomas. Over 80% of

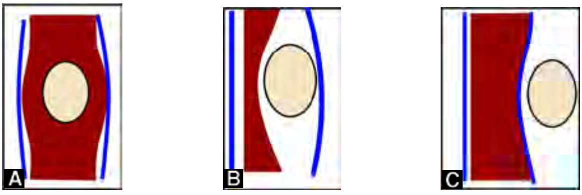
meningiomas occur in the thoracic region in middle-aged women and are very rare in the lumbar spine, whereas neurinomas occur at any level, at almost any age, and approximately equally in men and women. Tumoral calcification may occur in both.

The most common extradural tumors are metastases. These usually involve the vertebral bodies and neural arches, but malignant infiltration may spread widely in the epidural space without local bony involvement. Other disseminated malignancies such as myeloma and lymphoma are indistinguishable. Primary bone tumors are less common. Those most often responsible for spinal cord compression are aneurysmal bone cyst, benign osteoblastoma, chordoma and giant cell tumour. Expansion of the cord is the hallmark of an intramedullary neoplasm. Most cord tumors are hyperintense on T2-weighted images and hypo intense on T1-weighted images. Areas of increased T2 signal extending above or below the expanded cord segment represent micro infiltration of tumor or associated edema. Conventional MR techniques cannot reliably make this distinction. Gadolinium enhances areas of blood-brain barrier breakdown to help detect, characterize and define the extent of intramedullary neoplasms.

Focal areas of hemorrhage, intratumoral cysts or necrotic cavities can give cord tumors a heterogeneous appearance on MR scans. The signal intensity depends on the concentration of protein within the cysts and the specific components of hemorrhage that are present.

In general, the MR appearance of cord neoplasms varies widely, and making a specific diagnosis is difficult in most cases. An enhancing tumor in the conus is highly likely to be an ependymoma. In the cervical and upper thoracic cord, the frequency of ependymoma and astrocytoma is about equal. The classic features of hemangioblastoma include a cyst with an enhancing mural nodule. Fat signal components are an important clue for a lipoma or teratoma. Hematogenous metastases from breast or lung carcinoma and melanoma may produce a similar appearance to primary intramedullary neoplasms, although metastases may involve several segments of the cord and subarachnoid spread of tumor is common. Primary CNS lymphoma can, on occasion, involve the spinal cord.

SPINAL TUMORS—LOCATION A GUIDE



FIGS 5.55A TO C: SPINAL TUMORS—(A) SPINAL CORD (BLACK); (B) TUMOR (YELLOW) AND (C) DURA MATER (BLUE)

INTRAMEDULLARY	EXTRAMEDULLARY / INTRADURAL	EXTRAMEDULLARY/ EXTRADURAL
CORD EXPANSION	CORD COMPRESSION WITHIN THECAL SAC	CORD COMPRESSION OUTSIDE THECAL SAC

Location	Site	Example
1. Intramedullary	Within cord substance	Syringomyelia
2. Extramedullary, Intradural	Within cord covering, outside cord substance	Meningioma
3. Extradural	Outside cord substance and covering	Neurofibroma, disc

Spinal Tumors—Examples

Intramedullary	Extramedullary, Intradural	Extradural
Syringomyelia	Meningioma	Disc herniation
Ependymoma	Neurofibroma	Vertebral lesions
Cord odema/contusion	Meningitis	Epidural hematoma
Myelitis	Metastasis	Cold abscess

SPINAL TUMOR

INTRAMEDULLARY—EPENDYMOMA

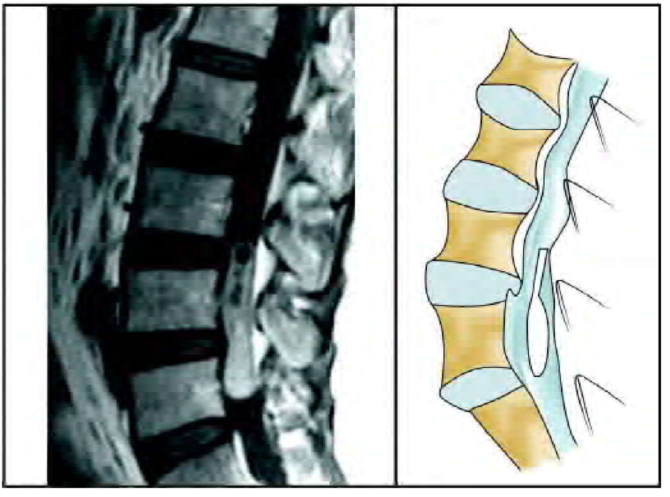


FIG. 5.56: T1W SAGITTAL WITH CONTRAST AGENT

A large intraspinal mass expanding the cord. The mass is arising near the filum-terminale. The mass shows heterogenous contrast enhancement

Blue line point to the intra-spinal mass

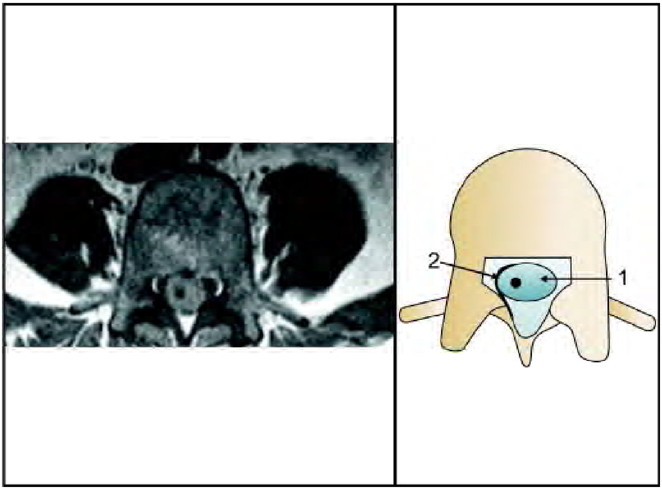


FIG. 5.57: T2W AXIAL

Note the centrally located, cord expanding mass showing contrast enhancement

1. Intraspinal, intramedullary mass
2. Displaced thecal sac

DISCUSSION

Most spinal cord neoplasms are malignant, and 90–95% are classified as gliomas, which constitute ependymomas or astrocytomas. Ependymomas are the most common intramedullary glial tumor in adults, whereas astrocytomas are most common in children. Cord ependymomas most commonly occur in the cervical region followed by the thoracic and lumbar region, respectively. However, the myxopapillary variant that contains abundant mucin is virtually always located along the filum-terminale.

MR shows a widened cord or a mass lesion involving the cauda and conus medullaris. Most spinal cord ependymomas are seen as centrally located, well-defined, iso- or hypointense relative to the spinal cord on T1-weighted and hyperintense on T2-weighted MR images. Enhancement is virtually almost always seen after the contrast administration. Myxopapillary ependymomas may appear hyperintense on T1-weighted MR image due to presence of abundant mucin and also are more prone to hemorrhage. Cysts may be seen in about 78–84% of ependymomas.

Radiologically, astrocytoma is a close mimicker of ependymoma. Ependymomas are central in location since they arise from central canal ependymal cells, whereas astrocytomas are eccentric with infiltrating borders as they originate from the cord parenchyma. Findings such as hemorrhage within the tumor and hemosiderin deposition or calcification are more frequent in ependymomas due to rich connective tissue stroma. Contrast enhancement is also intense and homogenous in ependymomas whereas it is patchy and irregular in astrocytomas.

Sagittal T1W and sagittal T2W MR images demonstrate heterogeneous mass with regions of T1 hypointense and T2 hyperintense signal corresponding to cysts and T1 and T2 isointense signal corresponding to solid parts of the tumor. Observe the hemosiderin ring on the surface of the tumor in the lower compartment representing chronic hemorrhage.

EXTRAMEDULLARY/INTRADURAL (Example 1)

ARACHNOID CYST

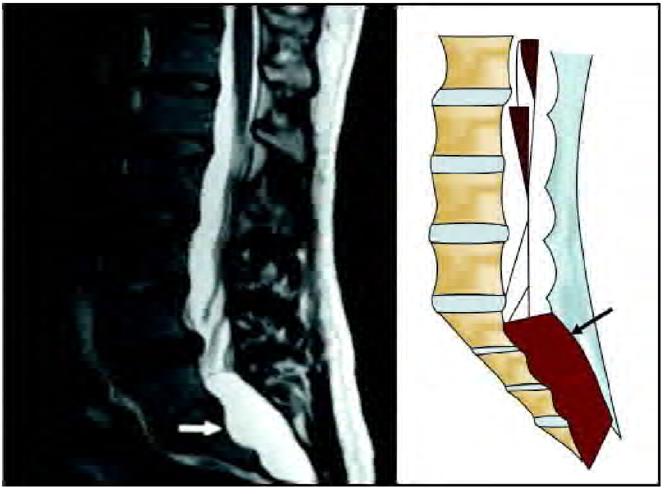


FIG. 5.58: T2W SAGITTAL

A lobulated cystic lesion (white arrow) is seen sacral thecal sac. The nerve roots are arching around the cyst

The blue arrow points to the lobulated lesion posterior to the sacrum

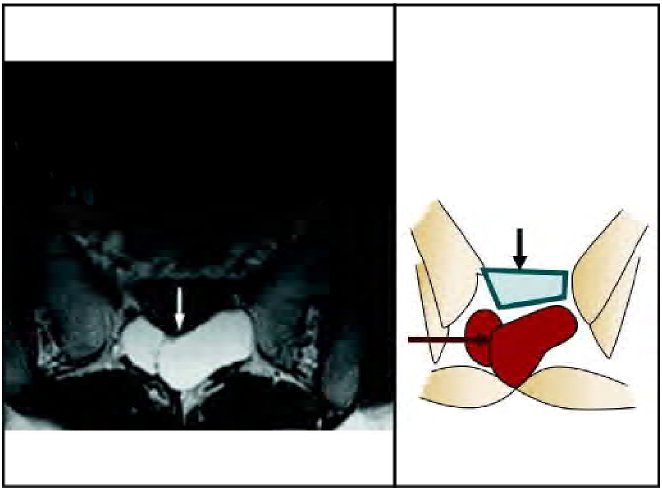


FIG. 5.59: T2W AXIAL

T2W axial white arrow shows a loculated cyst in the posterior thecal sac. The cyst shows signal similar to CSF in all pulse sequences

The red arrow point to loculated cyst.
The blue arrow to the thecal sac

DISCUSSION

This is rare in lumbar region. Most commonly seen in thoracic region, in females and is seen posterior to the cord. In MRI the cyst has the same signal intensity as the cerebrospinal fluid (CSF) in all sequences, unlike other cystic tumors. This is characteristic of arcachnoid cyst.

Spinal arachnoid cysts can be primary congenital cysts or secondary septations of the arachnoid. Most congenital spinal archnoid cysts are situated dorsal to the spinal cord.

If large, they can compress the spinal cord and lead to signs of myelopathy or pain. The symptoms may be aggravated in the upright position or under a Valsalva maneuver. On MR imaging, arachnoid cysts are isointense to CSF on all sequences. They are usually initially noted for their displacement of the spinal cord or of the cauda. High-resolution sequences with strong T2-weighting can be helpful in identifying arachnoid septation and the boundaries of the cysts. Important differential diagnoses are epidermoids and dural ectasias.

EXTRAMEDULLARY/INTRADURAL (Example 2) MENINGIOMA

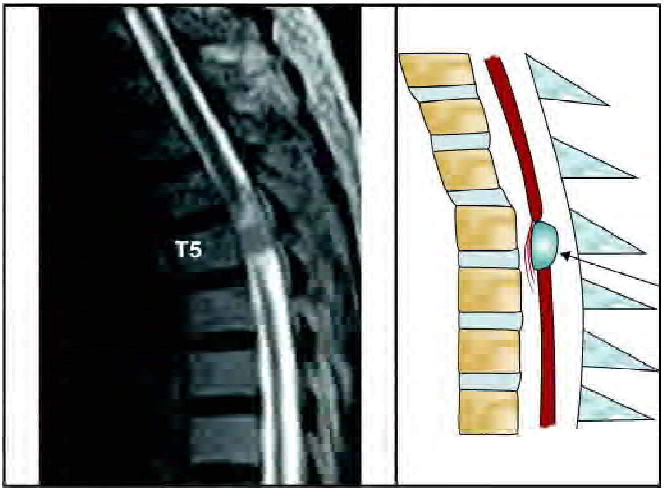


FIG. 5.60: T2W SAGITTAL

A well defined isointense oval mass with central necrosis is seen in the extra-medullary/intradural location. Note the displaced cord structures

Blue arrow shows a well defined extramedullary oval mass displacing cord

Meningiomas are the second most common tumor in the intradural extramedullary location, second only to tumors of the nerve sheath. Meningiomas account for approximately 25% of all spinal tumors. Most intradural spinal tumors are benign and potentially resectable. The prognosis after surgical resection is excellent. Most meningiomas are intradural and extramedullary. Occasionally, they can be purely extradural (7%) or intradural and extradural (6%).

MRI demonstrates the intradural extramedullary location of meningiomas. Lesions are usually isointense to spinal cord on both T1-weighted and T2-weighted images. Lesions are sometimes hypointense on T1-weighted images and hyperintense on T2-weighted images. Homogeneous intense enhancement of the lesion is seen after an intravenous injection of gadolinium-based contrast agent.

Most spinal meningiomas demonstrate broad-based dural attachment. On occasion, a densely calcified meningioma may demonstrate hypointensity on both T1-weighted and T2-weighted images. The spinal cord is displaced away from the lesion and usually compressed. The subarachnoid space above and below the lesion is widened, and a meniscus capping (MENISCUS SIGN) the lesion may be seen.

A meningioma with intradural and extradural components occasionally mimic a nerve sheath tumor, or a nerve sheath tumor with a predominant intradural component may mimic a meningioma. However, nerve sheath tumors usually have hyperintensity on T2-weighted images, whereas meningiomas usually are isointense to the spinal cord on T2-weighted images. Most meningiomas are lateral or dorsal, whereas most nerve sheath tumors are ventral. Furthermore, a mass lesion with both intradural and extradural components is most likely to be a nerve sheath tumor.

Intradural extramedullary tumors are much less common than extradural tumors. They include intradural extramedullary metastases, such as drop metastases or metastases from primary malignancies outside the central nervous system (CNS); meningiomas; nerve sheath tumors; arachnoid cysts; dermoids and epidermoids; and paragangliomas.

SCHWANNOMA (Example 3)

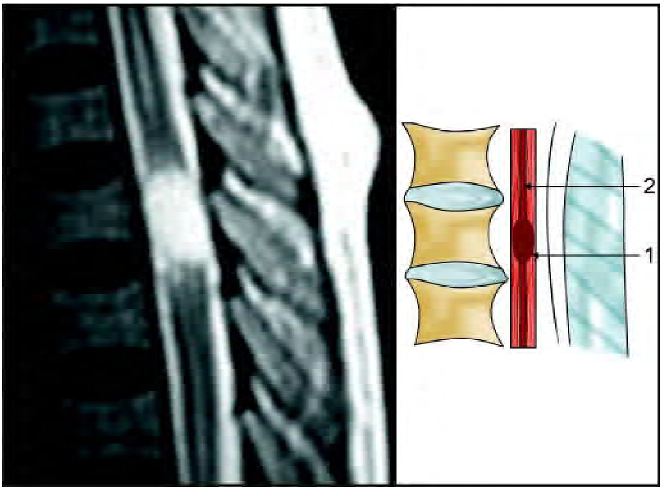


FIG. 5.61: T2W SAGITTAL

There is a well-defined hyperintense mass in the spinal cord. Note edema within the cord—white lines

1. Hyperintense mass
2. Cord edema

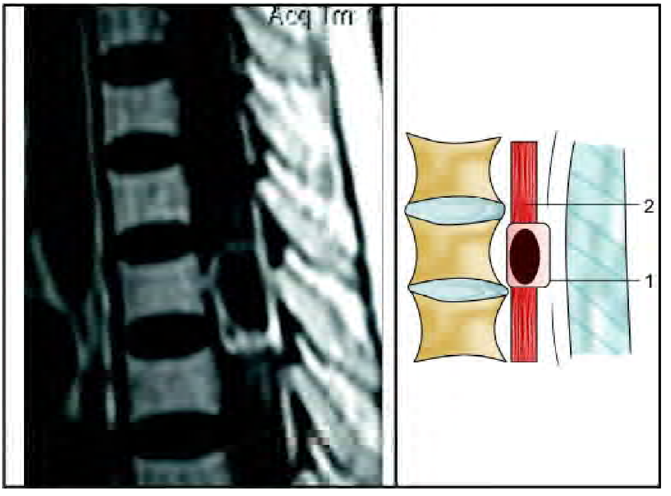


FIG. 5.62: T1W SAGITTAL WITH CONTRAST AGENT

A ring-enhancing mass is seen suggestive of schwannoma

1. Ring-enhancing mass
2. Spinal cord

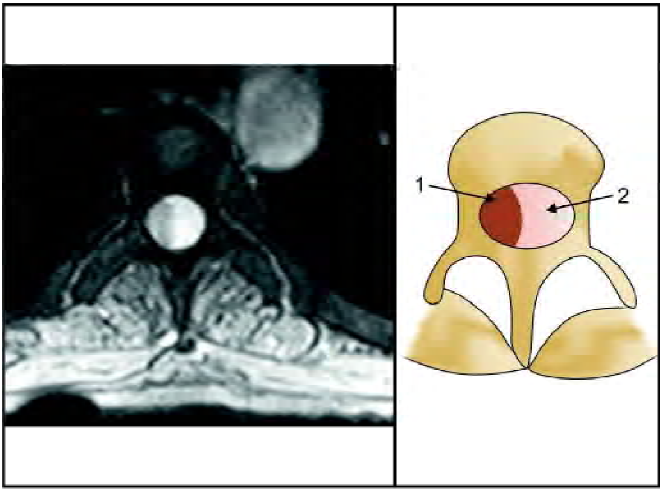


FIG 5.63: T2W AXIAL

The thecal sac is displaced laterally by extradural mass

1. Extradural mass
2. Thecal sac displaced laterally

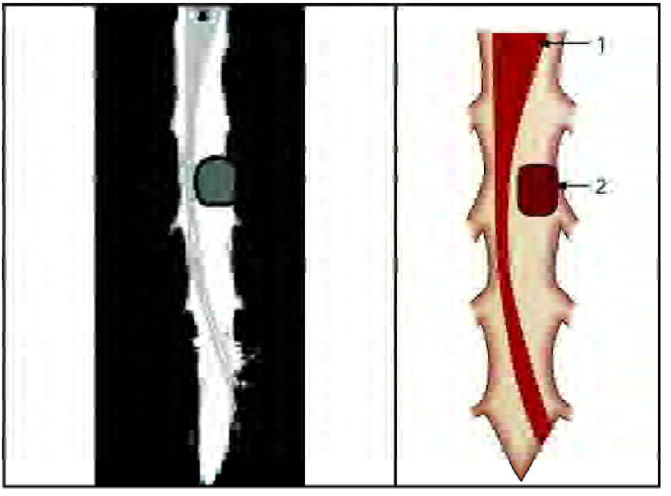


FIG. 5.64: MYELOGRAM—CORONAL VIEW

Note the characteristic location of the intraspinal mass. The mass is extramedullary, but intradural

1. Diplaced spinal cord within the thecal sac
2. Extramedullary, intradural mass arising close to nerve root

EXTRADURAL SCHWANNOMA

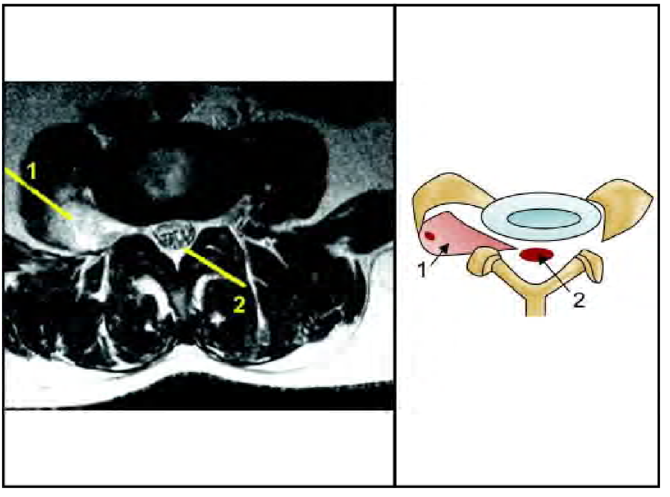


FIG. 5.65: T2W AXIAL

The yellow line 1 shows a well defined mass arising from the right neural foramen, displacing the psoas muscle. The yellow line 2 shows the cauda equina

1. Dumb-bell shaped mass
2. Cauda equina

Most common extramedullary, intradural spinal tumor is the neurofibroma. It has a characteristic dumb-bell shape and shows ring contrast enhancement. It widens the neural foramen and the intervertebral foramen.

Schwannomas are slow growing benign tumors. They are usually encapsulated, and rarely undergo malignant transformation. Benign schwannomas can occasionally

display degenerative changes that are encompassed by cyst formation, calcifications, hemorrhage and hyalinization. The lumbar region is one of the most common sites for occurrence of spinal schwannomas.

MRI of the spine reveals a well-defined intradural, extramedullary cystic mass lesion at the level of the L3/L4. The lesion is well defined, hyperintense in T2W tramsverse plane. The extramedullary location of this intraspinal tumor is well-demonstrated in all planes and in MR myelogram. There ring-enhancement of the lesion was well-shown in T1W images.

Schwannomas are benign, encapsulated nerve sheath tumors composed of proliferating Schwann cells. Alternate names for schwannoma are neurinoma and neurilemmoma.

Neurofibromas are benign, unencapsulated tumors of the peripheral nerves composed by proliferating Schwann cells mixed with fibroblasts.

Nerve sheath tumors (schwannoma + neurofibroma) represent the most common primary neoplasia (30%) in the spine as well as in the intradural extramedullary space (30%).

MRI provides an excellent delineation of nerve sheath tumors and their location relative to the dural sac, and the cord is depicted accurately in most cases Schwannomas and neurofibromas are mostly indistinguishable on imaging, although there are some hints that help in their characterization. They appear as solid, circumscribed masses, isointense to slightly hypointense on T1W images and hyperintense on T2W images compared with cord. Schwannomas often

demonstrate a heterogeneous signal on T2W images, corresponding to the mixed Antoni A and B pattern (i.e., compact areas and less cellular regions, respectively). A schwannoma may also present dominantly with one or the other pattern. On postcontrast T1W images, they show an intense contrast enhancement.

By definition a lesion is called a "giant schwannoma" if it (1) stretches over two vertebral levels or (2) extends extraspinally more than 2.5 cm or (3) extends into the myofascial plains.

Nerve sheath tumors include both neurofibroma and neurilemoma (schwannoma). They originate from Schwann cells of the myelin sheath that invest the nerve roots as they exit the spinal column. Schwannomas are usually solitary lesions and do not incorporate the nerve root. Neurofibromas are associated with neurofibromatosis and are generally multiple, and the nerve fibers become entangled within the tumor, making resection difficult without sacrificing the nerve. Nerve sheath tumors can be intradural, extradural or both, giving them a dumb-bell appearance.

Bone erosion with scalloping of the vertebral body margins or widening of the neural foramen with erosion of the pedicles is the hallmark of the nerve sheath tumors. Even in the absence of bone erosion, extension of a soft-tissue mass through the neural foramen with a dumbbell configuration is quite characteristic.

The signal characteristics of nerve sheath tumors are somewhat different from those of meningiomas. Nerve sheath tumors typically have a T1 that is slightly longer than or

equal to that of the spinal cord. Lengthening of the TR and TE to increase T2-weighting results in brightening of the tumor. T2-weighted images, particularly with fat suppression, provide good contrast between the hyperintense schwannoma, medium intensity paravertebral muscles, and hypointense fat.

Neurofibromas and schwannomas enhance brightly and uniformly with gadolinium. Enhancement is most helpful for intradural lesions, for detection of the smaller ones and definition of the larger ones. Gadolinium is less helpful for extradural lesions because the enhancing tumor becomes isointense to the surrounding fat. Fat suppression improves the contrast between enhancing extradural tumors and surrounding tissues.

SPINAL TUMOR—EXTRAMEDULLARY/ EXTRADURAL—CHORDOMA

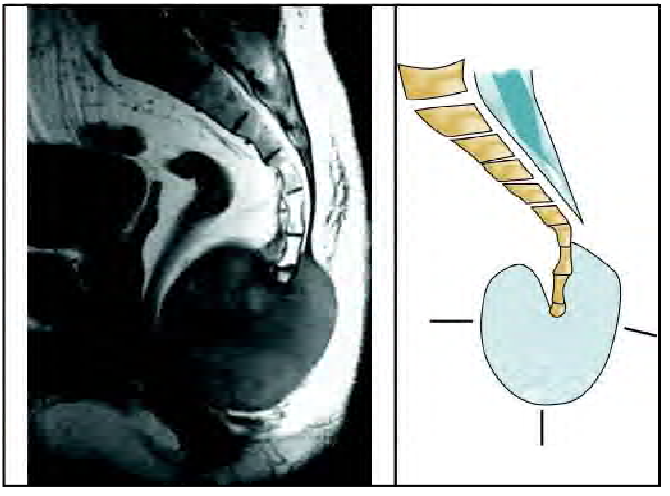


FIG. 5.66: T2W SAGITTAL

A large round mass is seen arising from the distal end of spinal cord. This intraspinal mass is extending to pelvic cavity and presenting as a pelvic mass. The surgery and biopsy confirmed the tumour as chordoma

The blue lines show a mass in end of spinal cord, extending into pelvic cavity

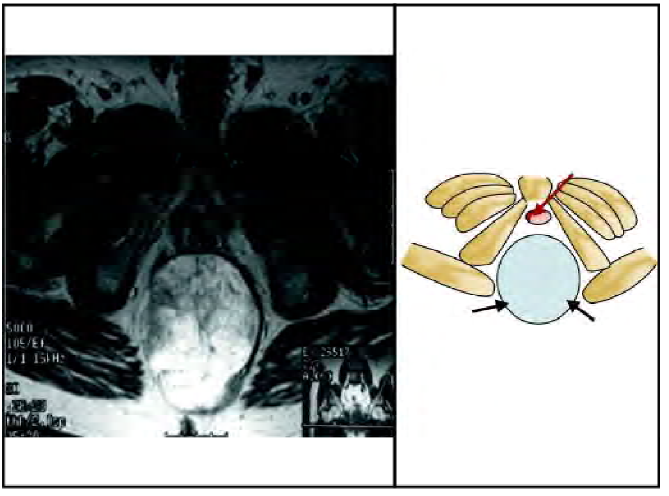


FIG. 5.67: T1W AXIAL

The midline oval mass is compressing the pelvic organs like rectum

The blue arrow shows a spinal mass displacing the rectum anteriorly (red arrow)

DISCUSSION

A chordoma is a malignant tumor arising from the embryonic remnants of the notochord. Histologic identification of physaliphorous cells confirms the diagnosis. On T1W imaging the lesion is heterogeneous and hypointense to isointense to bone marrow. On T2W it is hyperintense to CSF and intervertebral discs may have septations or destroyed intratumoral bony trabeculae. On postcontrast T1W imaging enhancement is variable but usually moderate.

Etiology: Arise from remnants of the embryonic notochord.

Pathology: Typical chordomas have vacuolated physaliphorous cells with a myxoid matrix. Chondroid chordomas have cartilaginous foci within the matrix.

Incidence: 1–2% of primary malignant bone neoplasms. Most common primary sacral neoplasm.

Population: Occur at any age. Craniovertebral chordomas peak at 30–50, sacrococcygeal chordomas peak at 40–60. 2 to 1 male predominance.

Location: 50% sacrum/coccyx, 35% skull base, 15% vertebral bodies.

CT characteristics: Destructive, lytic bone lesion associated with a soft tissue mass. Often has cystic areas and calcification in 30–70%. The calcification is postulated to be residual bone fragments.

MR characteristics: T1-Hypointense to isointense soft-tissue mass that occasionally has high signal cysts and/or signal voids in areas of residual bone. T2 and Proton Density-Mass with signal intensity equal to CSF. Enhancement is variable, from scant to striking.

Differential diagnosis includes: In the area of the clivus the following neoplasms can look similar to chordoma-chondrosarcoma, nasopharyngeal, squamous cell carcinoma, metastasis, invasive pituitary adenoma, meningioma.

SPINAL STENOSIS

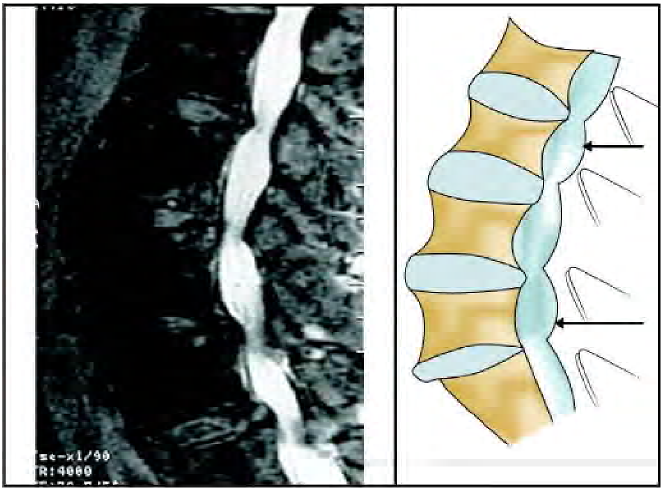


FIG. 5.68: T2W SAGITTAL

T2W sagittal image shows the typical hour-glass deformity of spinal canal due to marked spinal stenosis

Blue arrows indicate spinal stenosis due to ligamentous hypertrophy

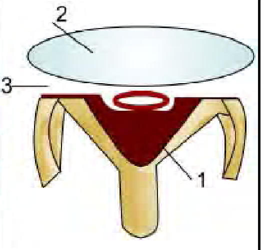


FIG. 5.69: T2W AXIAL

The spinal canal diameters are markedly reduced by the bulging disc posteriorly, thickened ligamentum flavum and facet arthritis anterolaterally

1. Hypertrophied ligamentum flavum
2. Degenerated bulging disc
3. Facet joint arthritis

DISCUSSION

Spinal stenosis is a condition, usually congenital, in which the diameters of the spinal canal are smaller than those of the normal persons. An AP diameter of the spinal canal, at any level, of less than 10 mm is indicative of spinal stenosis. The stenosis is usually due to hypertrophy of the articular processes, thickening of ligamentum flavum. The lower limit of normal AP diameter in the lumbar spine

is 15 mm and for the transverse diameter is 20 mm. The symptomatology of narrow spinal canal varies according to the segment and level involved. In the lumbar area radiculopathy, sciatica and cauda equina syndrome are the most common symptoms. The narrow spinal canal usually becomes symptomatic when additional degenerative processes like osteophytes, facet hypertrophy, disc protrusions, and ossification of ligaments further reduce the diameters and worsen the extradural compression.

Spinal stenosis also includes any type of narrowing of the spinal canal, nerve root canals, or intervertebral foramina. Two broad groups are: acquired (usually related to degenerative changes) and congenital or developmental. Developmental stenosis can be exacerbated by superimposed acquired degenerative changes. In the acquired type, there is no association between the severity of pain and the degree of stenosis. The most common symptoms are sensory disturbances in the legs, low back pain, neurogenic claudication, weakness, and relief of pain by bending forward. The imaging changes are in general more extensive than expected from the clinical findings. Patients with symptoms referable to spinal stenosis tend to have narrower spines than asymptomatic patients. The degree of stenosis is not static, and extension worsens the degree of central and foraminal stenosis by 11%, while flexion appears to improve it by an average of 11%. Some evidence suggests that disk degeneration, narrowing of the spinal canal, and degenerative changes in the facets and spinal ligaments contribute to stenosis and that instability increases with age.

OSTEOPOROSIS

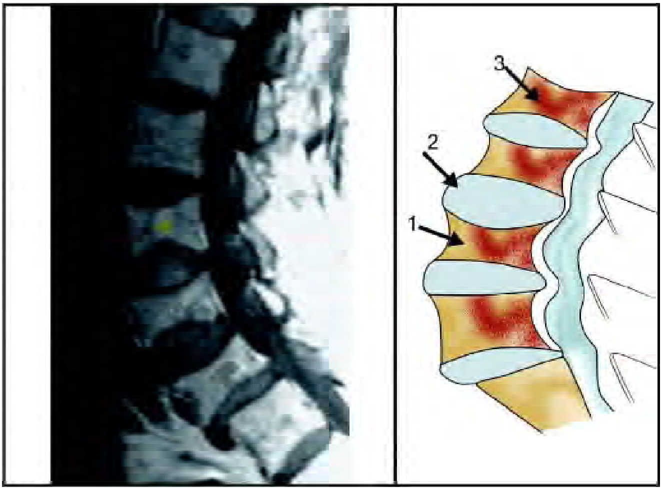


FIG. 5.70: T1W SAGITTAL

This image shows multiple vertebral collapse, with bulging discs giving the fishmouth appearnace. The overall increased bone marrow signal is due to osteoporosis

1. Collapsed vertebral body
2. Bulging disc
3. Increased signal due to osteopenia

DISCUSSION

Osteoporosis is a disease of bone that leads to an increased risk of fracture. In osteoporosis the bone mineral density (BMD) is reduced, bone microarchitecture is disrupted, and the amount and variety of proteins in bone is altered. Osteoporosis is defined by the World Health Organization (WHO) in women as a bone mineral density 2.5 standard

deviations below peak bone mass (20-year-old healthy female average) as measured by DXA (Dual X-ray Absorbitometry); the term “established osteoporosis” includes the presence of a fragility fracture. Osteoporosis is most common in women after menopause, when it is called postmenopausal osteoporosis, but may also develop in men, and may occur in anyone in the presence of particular hormonal disorders and other chronic diseases or as a result of medications, specifically glucocorticoids.

POSTOPERATIVE SPINE

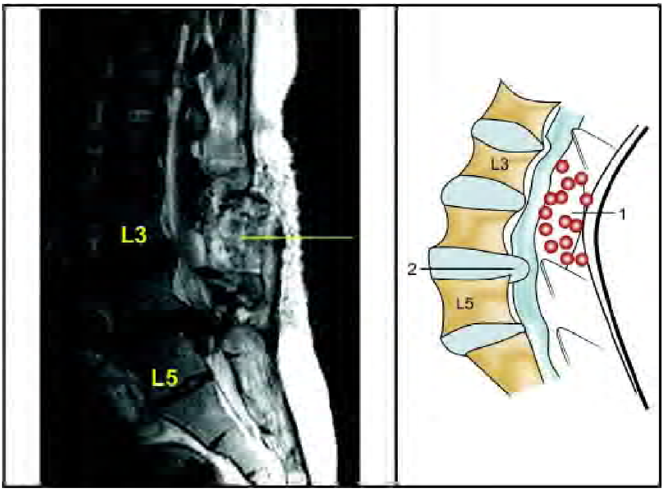


FIG. 5.71: T2W SAGITTAL

Postoperative spine shows evidence of surgery—laminectomy (yellow line)
The L4/L5 disc shows disc herniation

1. Post laminectomy spine
2. Disc herniation

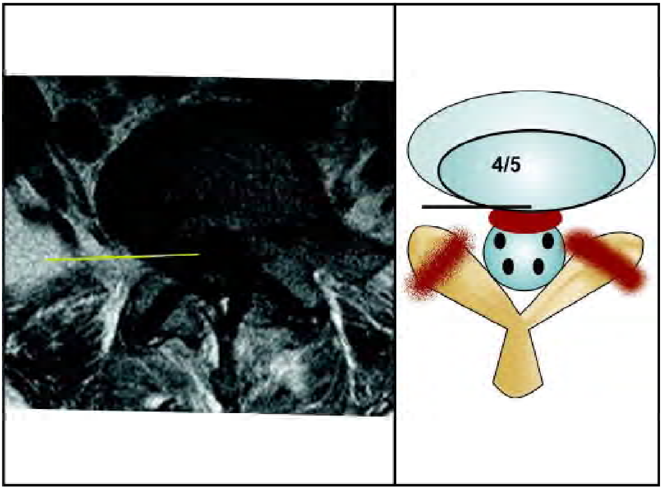


FIG. 5.72: T2W AXIAL

Disc herniation in a postoperative patient (yellow line). The disc surgery was done at a higher level

Blue line shows a recurrent disc herniation

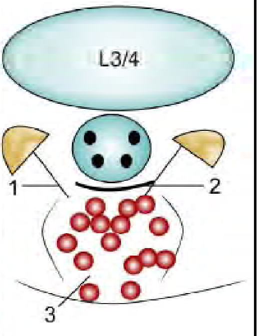


FIG. 5.73: T2W AXIAL WITH LAMINECTOMY

The yellow lines point to the laminectomy site

1. Epidural scar
2. Post-laminectomy site
3. Postoperative soft tissue and skin changes

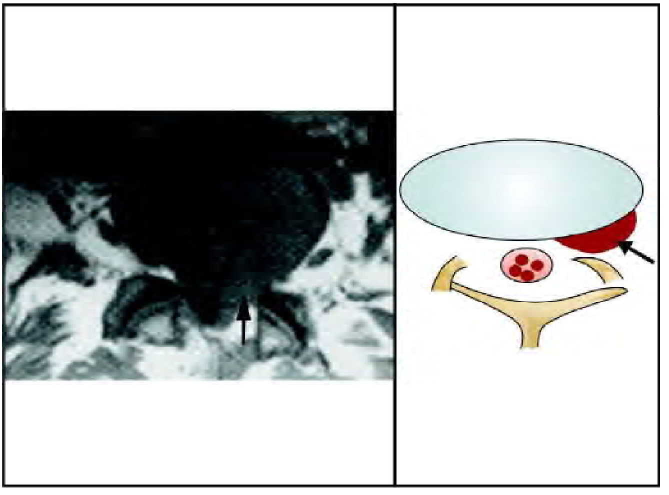


FIG. 5.74: T1W AXIAL WITH CONTRAST AGENT

In this postoperative case there is a non-enhancing epidural mass suggesting recurrent disc herniation. This is unlike an epidural scar which shows contrast enhancement

The arrow points to left side recurrent disc herniation

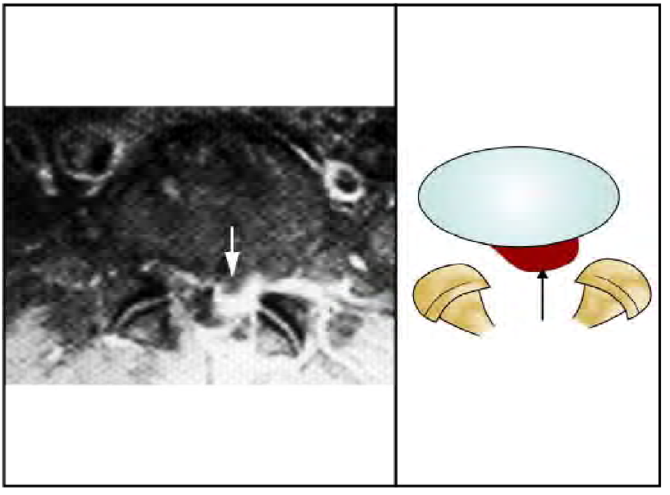


FIG. 5.75: T1W AXIAL WITH CONTRAST AGENT

In this postoperative case there is a contrast enhancing epidural mass, corresponding to the operated site. This suggests an epidural scar rather than a recurrent disc herniation. Note there is an evidence of laminectomy

The arrow points to contrast enhancing epidural scar

DISCUSSION

A recurrent herniated disc is an avascular, well-defined, low-intensity mass that does not enhance on early postinjection images. It has a well-defined margin and is usually located in the anterior epidural space contiguous with or near the native disc space. An epidural scar is a vascular structure with ill-defined margins that tends to encircle the thecal sac and roots. Anteriorly, it consistently enhances even years after surgery.

In the early postoperative period, interpretation of the MR images is extremely difficult. The presence of fat graft, hematoma, gas, and inflammation complicates the observed signal intensities. Moreover, recurrent disc and epidural scar exhibit similar topographical and signal characteristics. After about one month, the acute postoperative changes resolve, making it easier to distinguish scar from disc. As before surgery, recurrent disc is often in continuity with the parent disc. Discontinuity in the annulus fibrosus is not entirely reliable because it can result from the surgical incision as well as from disc rupture. Unless the disc material has become separated as a free fragment or sequestration, it remains similar in signal characteristics to the parent disk on both T1- and T2-weighted images. In general, herniated discs are relatively well-defined and, in some cases, have a hypointense rim.

On the other hand, epidural scar has poorly defined margins and is either isointense or hypointense on T1W sequences compared to the adjacent disc. With more T2-weighted, scar generally increases in signal, but to a lesser degree many months or years after surgery. In addition, if the soft-tissue abnormality can be followed posteriorly along the lateral margin of the spinal canal to the region of the laminectomy, it is probably scar. Retraction of the thecal sac to the side of the soft tissue is another sign favoring postoperative scar.

In the immediate postlaminectomy period, the signal from normal bone and ligament is replaced by edema at the resection site. This is heterogeneously isointense to muscle on T1-weighted images and increased on T2-weighted images. In a purely decompressive laminectomy without discectomy,

significant mass effect on the thecal sac is unusual unless a hematoma is present. Between 6 weeks and 6 months after surgery, the postoperative edema is replaced by scar tissue posterior to the thecal sac. The scar appearance can range from low to high signal intensity on T2-weighted images.

Gadolinium should be used routinely in the postoperative back because it is a valuable aid for differentiating the various postoperative tissues. The enhancing scar clearly identifies nerve roots trapped within the scar and outlines any retained or recurrent disc fragments. A disc fragment induces a local inflammatory reaction, and vascular granulation tissue often forms about its perimeter. As a result, the perimeter of a herniated disc may enhance with gadolinium, but the central part will not, thus distinguishing it from epidural scar.

Lumbar disc surgery involves part or complete laminectomy for access, partial facetectomy to free the lateral recess, and removal of accessible disc material from spinal canal and disc space, in varying combinations. Each component results in the appearance of epidural granulations, of variable amount and extent, and finally in mature fibrous tissue. The importance of this as a cause of recurrent symptoms after operation has been greatly diminished by imaging studies in which both the prevalence and severity of these processes have been shown to be entirely similar in patients who are pain-free after operation. However, it is still useful to distinguish these reactive processes from recurrent or residual disc material, the presence of which continues to be a firm indication for re-operation.

FACET JOINT ARTHRITIS

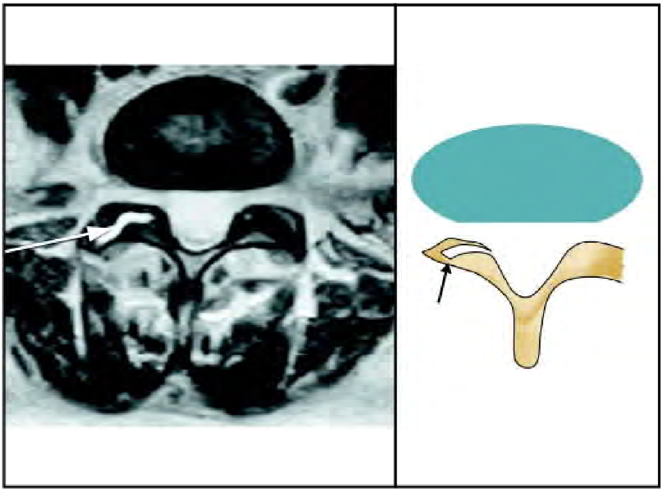


FIG. 5.76: T2W AXIAL

The right side facet joint shows widened joint space due to fluid collection. There is bright signal due to joint effusion. (Any fluid, in any place show bright signals in T2W sequences.)

The blue arrow points to right sided facet joint arthritis

DISCUSSION

The facet joints are a pair of joints in the posterior aspect of the spine. This joint is one of the most common sources of low back pain. The two common mechanisms for this generation of pain are either (1) direct, from an arthritic process within the joint itself, or (2) indirect, in which

overgrowth of the joint (e.g. joint hypertrophy or a synovial cyst) impinges on nearby structures. Like any synovial joint, degeneration, inflammation, and injury can lead to pain with joint motion, causing restriction of motion secondary to pain. The neural foramen is bordered by the superior articular process, pars interarticularis, and posterior portion of the vertebral body. Facet joint hypertrophy or a synovial cyst can contribute to lateral and central lumbar stenosis, which can lead to impingement on the exiting nerve root.

- The main utility of MRI is for excluding pathologies other than Facet-joint arthropathy, because many degenerative changes in the Facet-joint are asymptomatic. Similarly, true Facet-joint-mediated pain may be present despite a normal MRI examination.
- MRI provides detailed anatomic images of the soft structures of the spine, such as the intervertebral discs, which often show degenerative changes before—Facet joint pathology.
- MRI also may illustrate nerve root entrapment secondary to—Facet joint hypertrophy or a synovial cyst and may help visualize the intervertebral foramen; however, Facet-joint pathology may be present despite normal imaging study findings.

The normal facet joints show a uniform joint space of 2–4 mm, without osteophytosis or subchondral bone reaction. Mild (grade 1) osteoarthritis is characterized by narrowing of the facet joint space (< 2 mm) and/or small osteophytes, and/or mild articular process hypertrophy. Moderate (grade 2) osteoarthritis is characterized by narrowing of the facet

joint space (< 2 mm) and/or moderate osteophytes, and/or moderate articular process hypertrophy and/or mild subarticular bone reaction (erosions). Severe (grade 3) osteoarthritis was characterized by narrowing of the facet joint space (< 2 mm) and/or large osteophytes, and/or large articular process hypertrophy and/or severe subarticular bone reaction (erosions and/or cysts).

FACET JOINT CYST

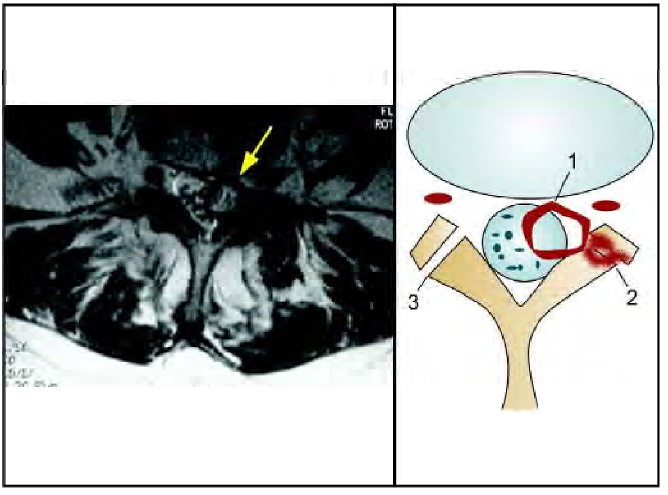


FIG. 5.77: T2W AXIAL

In this T2W axial image the yellow line indicates a thick walled left sided facet joint cyst with significant mass effect on the thecal sac

1. Facet joint cyst. in left side
2. Left facet joint. arthritis
3. Normal right facet joint

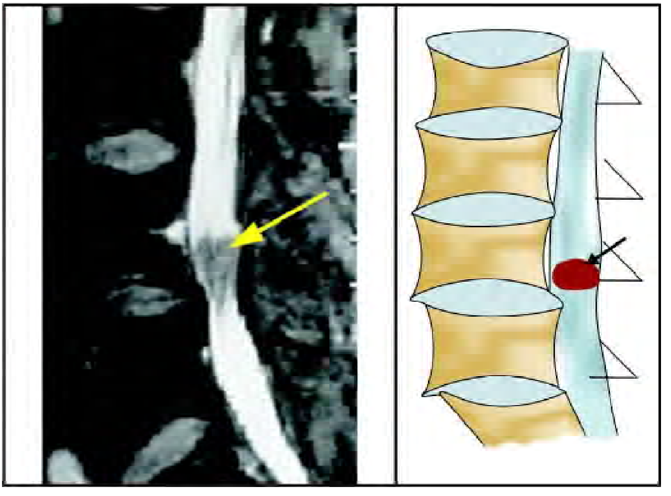


FIG. 5.78: T2W SAGITTAL

In this T2W sagittal image the yellow line shows of a facet joint cyst originating from the left L4–L5 facet joint causing significant mass effect against the thecal sac

In this line diagram the blue line indicates an extradural cystic mass compressing the thecal sac

DISCUSSION

With chronic irritation, tears can develop in the capsule of the facet joint and fluid can migrate through the capsule into the epidural space and form a cyst. The cysts are usually of simple fluid intensity (dark on T1-weighted and bright on T2-weighted images); however, they may be brighter on T1-weighted and darker on T2-weighted images if the fluid contains proteins. These cysts can exert mass effect on or can narrow the canal, resulting in nerve root symptoms. Synovial cysts can be resected surgically or may be aspirated

under CT guidance. On the basis of sagittal post-contrast T/1 study the other diagnoses such as schwannoma, intradural metastasis, extruded disc, ependymoma or infectious cyst should be entertained. The proximity to facet joints makes the diagnosis more likely. The cysts are degenerative in nature and are common after 5th decade. They may bleed and have different signal on different techniques.

Juxtafacet cysts can be formed in the spinal canal, most often near an articular facet or in a yellow ligament, and possibly causing neurologic symptoms mimicking disc herniation. These cysts are diagnosed by characteristic findings on magnetic resonance imaging (MRI) or computed tomography (CT) scan. Pathologists divide these cysts into synovial and ganglion types but they do not have any prognostic significance.

- Intraspinal synovial cysts are extradural lesions that arise from the synovial lining of the facet joints.
- Most cysts are found at the L4–L5 facet joint, as this is the level where the most biomechanical spinal motion occurs.
- Synovial cysts may extend into the neural foramen or spinal canal and result in symptomatic radiculopathy, spinal stenosis, or both.
- Patients may also experience neurologic claudication if the cyst is large enough to cause substantial spinal cord compression.
- The differential diagnosis for synovial cysts includes arachnoid cysts, Tarlov cysts, schwannomas, and migrated herniated disc fragments.

- Intraspinal synovial cysts typically appear as a sharply marginated epidural mass in which the contents most commonly appear isointense to cerebrospinal fluid on T1-weighted images and hyperintense to cerebrospinal fluid on T2-weighted images.
- Attenuation of intraspinal synovial cysts on CT images correlates directly with viscosity of the cyst contents.

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